A REVIEW ON POWDER METALLURGY OF ALUMINIUM METAL MATRIX COMPOSITES

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ABSTRACT:-

Powder Metallurgy (P/M) is playing a vital role to synthesize variety of materials in the field of aerospace, automobile, ordnance, petroleum and petrochemical industries. P/M is an outstanding process to produce components with good mechanical and tribological properties such as strength, hardness, impact resistance and wear resistance. Recently metal matrix composites (MMC) replace conventional alloys because of their extraordinary characteristics. Currently Aluminium, Copper, Magnesium, Titanium and Iron have been used as matrix materials and materials like Tic, Sic, B4C, WC, Cr3C, TiO2, ZrO2, Gr, MoS2, and Si3N4 have been used as reinforcements to synthesize metal matrix composites. When compare P/M with other manufacturing methods, it offers ordered microstructure with improved physical, mechanical and tribological properties. From these, powder metallurgy could be commented as an extremely active and cost-effective method when compare with other process. This paper explains the selection suitable process parameters for synthesize MMCs using P/M technique. This paper made an attempt to present the mechanical and tribological properties of various composites fabricated through powder metallurgy technique.

Keywords: *Powder metallurgy, Metal matrix composites, Mechanical properties*

INTRODUCTION:-

In the present scenario Aluminium, Copper, Magnesium have been used as matrix components and materials such as Tic, TiB2, Sic, B4C, WC, Cr3C, TiO2, ZrO2, Gr and MoS2 as replacements for the synthesis of composites of metal matrixes. It provides ordered microstructure with improved mechanical and tribological properties when compared powder metallurgy with other manufacturing methods.

LITERATURE REVIEW:-

Koththavasal R. Venkatachari And Rishi Raj [1] Studied shear deformation and densification of powder compacts, the densification rate experiments resulted in a measurement of the intrinsic sintering pressure. It was found to be 0.8 Mpa at 0.7 density and decreased 0.4 Mpa at 0.95 density. The calculation was consistent with the microstructural finding that the numner density of pores was lower but with densification the size of the pores became larger.

R. Narayanasamy and K. S. Pandey [2] Cylindrical preforms of three initial theoretical densities (75, 80 and 90 %) and three initial aspect ratios (0.36, 0.54 and 0.72) were prepared using a suita ble die, a punch and a die bottom insert on a 0.60 Mcapacity hydraulic press. Experimental tests onsintered aluminum 3.5 % alumina powder compositecompared to preforms with higher initial Aspect ratios, preforms with lower initial aspect ratios displayed improved densification, subject to the situation where the original preform densities were kept constant. The Poisson ratio w.r.t., however, showed three distinctphases of the fractional theoretical density achieved, namely a steep rise, a steady state, followed by a rapid rise approaching the value of 0.5 in the near vicinity of the theoretical density.

R. Narayanasamy, T. Ramesh, and K. S. Pandey [3] In order to determine the strain hardening phenomenon for the study of plastic deformation, experiments on aluminium iron powder composite prefoems were investigated. Sintered has three different aspect ratios, namely 0.44, 0.45 and 0.75, with two different percentage points of iron content (0 % and 2 %) and three different sizes of iron particles, namely -53 +45 µm, -75 +63 µm and -106 +90 µm. For each aspect ratio and iron particle sizes, the strain hardening exponent 'n' and the strength coefficient 'K' have been obtained. For the distinct addition of iron powders and also for the various iron particle sizes for different aspect ratios and for different stress state conditions, there is a greater shift in the values of 'n' and 'K'.

R. Narayanasamy, T. Ramesh, and K. S. Pandey [4] Experimental studies on aluminium - 3.5% composites of alumina with three distinct aspect ratios (height to diameter ratio) 0.35, 0.56 and 0.72 and two relative densities of 0.80 and 0.90. Ceramic coating applied to green specimens and si ntered in electric muffle furnace at a temperature of 550 ± 10^0 c and cooled within the furnace itself. Experimental studies have shown that lower aspect ratio preforms have demonstrated elevated stress levels with the initial density of preforms of 0.80. However, the above finding is different with the higher initial preform density (0.90) at higher axial strains.Instant strain hardening exponent (ni) and intensity coefficient (Ki) are higher for triaxial stress condition independent of the original preform density and as pect ratio as compared to uniaxial and plane stress conditions.

R. Narayanasamy, T. Ramesh, and K. S. Pandey [5] Studies were done on cold forging of aluminium – 3.5 % aluminium powder composites under triaxial stress conditions with three different aspect ratios of 0.35, 0.56 and 0.72 with three different initial preform relative densities, namely 0.72, 0.80 and 0.88. On the basis of the dimensional performance and density estimation, a new express ion was suggested for the determination of the radius of the barrel radius curvature.
For the determined and estimated radius of barrel curvature, a straight-line relationship was observed and an exponential relationship was found between the parameters of the stress ratio and the relative density.

R. Narayanasamy, V. Anandakrishnan, and K. S. Pandey [6] Studies were conducted on Deformation behaviour the aluminium–3.5 % alumina powder composite in the case of triaxial stress state setting. Cold upsetting of intial preform density sintered composites with deferent as pect ratios was calculated with and without annealing and densification behaviour of the preforms under triaxial stress state condition and the densification behaviour of preforms was calculated taking into account the influence of both geometric work-hardening and work-hardening matrix The rate of densification is lower when the initial preform relative density is 0.72 and 0.8, due to the fact that only geometric hardening is dominant.

R. Narayanasamy et.al [7] - [8] During the disruption of aluminium iron composite activity with various particle sizes and 0 to 10 % of iron content under different stress state conditions of the uniaxial, the plane and the triaxial, studies were conducted on the constitutive relationship for porous powder metallurgy pieces. Sintered specimen were prepared and cold forged with aspect ratios of 0.44 and 0.7 with preform densities of 0.8 to 0.92. Studies showed that there is a tremendous variation in the above parameters for different iron particle sizes and iron contents, for different initial preform densities and for different stress state conditions. Composite preforms of Al-Fe were measured and found to achieve the peak value when the density of deformation or packing is at a low value. In comparison, the value of n_i and k_i reduced and was observed to be stable. It was also observed that the iron particle size of the preforms played a predominant role in affecting both ni and ki. The effect on work hardening of the iron content, the iron particle size spectrum and the original aspect ratio of the preforms has been extensively investigated. Review of the experimental details showed that the with declining values of the iron powder particle-size range, strain-hardening exponent n increased and was also observed to be greater for lower aspect ratio preforms compared to higher aspect ratio preforms. The finer iron particle dispersoids displayed an improved rate of work hardening regardless of the original aspect ratio and the iron quality, whereas coarser iron particle-size dispersoids displayed a minimum amount.

R. Narayanasamy, T. Ramesh, and K. S. Pandey [9] Aluminium iron powder metallurgy composites have been studied under triaxial Stress state condition with multiple percent iron composite additives 2 %, 4 %, 6 %, 8 %and 10 % with various iron particle sizes, namely -53 +45 µm, -75 +63 µm and -106 +90 µm. On the circular radius of curvature and contrasted with the experimentally determined barrel radius, a new empirical relationship for the determination of barrel radius is proposed. For the measured and determined radius of barrel curvature, a straightline relationship was observed and an exponential relationship was found between the parameters of the stress ratio an d the relative density.

Baba Gowon et al.[10] Studied making the full density brass and copper infiltrated W-brass. It was observed that after infiltration the brass infiltrated W-brass has the highest densification (99.99%) and hardness (137Hv).

Alberto Molinaria et al. [11] Studied During the uniaxial compaction of the powder mix a new densification equation was calculated for uniaxial cold compaction of four low alloy steel powders from the association between deformation and mean axial stress. The data collected by the press control unit was used for this purpose and the equation describes the continuous increase in density achieved by increasing the compaction pressure.

Sai Mahesh Yadav Kaku et al. [12] Studied Impact of distortion is concentrated on Al, Al - 2ZrB2, Al - 4Cu, Al - 4Cu - 0.5Mg, Al - 4Cu - 2ZrB2 and Al - 4Cu - 0.5Mg - 2ZrB2 made through PM. It was discovered properties of composites improved with alloying and fortification ZrB2. Al - 4Cu - 0.5Mg - 2ZrB2 seemed to have higher hardness when contrasted with different composites.

Sai Mahesh Yadav Kaku et al. [13] Studied the effect of deformation and densification and corrosion behavior of Al - ZrB2 composites by powder metallurgy method with various particulate weight rates of ZrB2 0, 2, 4 and 6 wt. % at three perspective proportions of 0.35, 0.5, and 0.65, individually. It was found Densification is improved with the expansion in temperature during distortion process. After deformation lower the aspect ratio higher the densification. Hardness of the composites increments with densification. Hardness is expanded with increment in the measure of ZrB2 in the composite. Increasing the densification decreases the corrosion rate. Al + 2% ZrB2 with upgraded properties is similarly densified as unadulterated Al and has roughly equivalent corrosion rate as unadulterated Al.

Siddhartha Tiwari et al. [14] Contemplated sintering weight of Green compacts of Al - 6.23 wt% Fe powder particles were created under differing compaction pressures, and these manufactured green compacts were sintered over a progression of temperatures (430 ˚C – 590 ˚C). So as to accomplish most extreme sintered thickness in the manufacture of Al - Fe (Al - 6.23 wt% Fe) metal grid composites, ideal sintering temperature is seen as 550˚C. Sintered density increments with increment in sintering temperature up to 550˚C and diminishes with further increment in temperature. A drop in sintered thickness, that is, growing, is found at 590˚C for all the green compacts. This growing conduct is considered to happen because of the development of overabundance opening and Al-Fe strong arrangement of lower thickness. These marvels can be all around portrayed with the assistance of the Kirkendall effect. Sintered thickness is found to increment with a higher rate for the green compacts of lower green thickness when contrasted with that of higher green thickness.

N.Vijay ponraj et al. [15] Studies were yielded out to assess the first preformed density and initial aspect ratio on the densification conduct of sintered Copper 7% Tungsten composite. The preform had 0.85 is the initial theoretical density. Aspect ratio has been taken 0.4, 0.6 and 0.8. Properties of Copper Tungsten composites regarding lateral strain, linear strain and true stresses were assessed and plotted. Studies uncovered that higher pressure and higher strain esteems are gotten in composite when contrasted with the Tungsten powder. The composite of Copper 7%W got at 750^0C. The Composite got the highest stress and strain at lower aspect ratio when compared to the composite preforms obtained at other aspect ratio.

Rajeshkannan Ananthanarayanan et al. [16] Studies were conceded out to evaluate the initially preformed density and initial aspect ratio on the densification behavior of sintered Al, Al - 2WC and Al - 2WC - 4Fe3C preforms were contemplated Pure Al demonstrated higher width and stature endure crack contrasted with Al - 2WC and Al - 2WC 4Fe3C. Addition of tungsten carbide to pure Al decrease the strain value of both at fracture, while further adding iron carbide to aluminium and tungsten carbide upgraded the previous stain esteems at break.

B. Chaitanya et al. [17] Studies were yield out Al - 4Cu - 0.5Mg - 2SiC composite is set up through powder metallurgy route. It was discovered that The hardness of the composite expanded with an alloying and with the expansion of SiC particles. The SiC particles added to the alloy matrix are along the grain limits in the sintered composite. The composites twisted at lower temperature requires higher burdens to deform than the composites disfigured at higher temperatures. The composites distorted at lower temperatures seemed to have high hardness upon examination with composites deformed at high temperatures.

Krishna Chaitanya. B et al. [18] Studied Properties Evaluation of Al - Sic Powder Metallurgy Preforms Al - 4Cu, Al - 4Cu - 2SiC, Al - 4Cu - 0.5Mg and Al - 4Cu - 0.5Mg - 2SiC compound composites are set up through powder metallurgy route. The hardness of the compound composites expanded with alloying addition of Mg and reinforcement expansion of SiC particles. The expansion of SiC particles to the preform the hardness and strength expanded, while the extent of straining diminished. With both alloying expansion of Mg and SiC molecule expansion to Al - 4Cu matix the hardness expanded by 37% and strength expanded in the came about composite grid Al - 4Cu - 0.5Mg - 2SiC.

Sai Mahesh Yadav Kaku et al. [19] Studies were conducted on strain hardening behavior and its effect on on Properties of ZrB2 Reinforced Al Composite Prepared by Powder Metallurgy Technique. Prepared various composites, the incremental weight percentage of ZrB2 (0, 2, 4 and 6) are added to the aluminium matrix. Pressureless sintered Al – ZrB2 composite is performed with strain hardening behavior. The amount of strain decreases with ZrB2 material at set stress hardening conditions. Composite hardness is found to increase with extent of composite strain hardening.

R. Narayanasamy et al. [20] Studies on Workability studies on cold upsetting of Al–Al2O3 composite material under various stress state conditions, namely uniaxial, plane and triaxial stress states. Upsetting of Al–Al2O3 powder metallurgy compacts with different perspective proportions and starting preform densities were completed and the working conduct of the powder compacts at different state conditions was computed. By increasing the initial preform fractional density and lower the aspect ratios increases the stress formability index.

Md. Ahasana et al. [21] Experimental investigation is done on the modelling aspects of Al-TiB2 composites hot deformation and densification behaviour are explored. A constitutive relationship was established which could relate the flow stress to the strain at different temparatures 200˚C, 300˚C, 400˚C and 500˚C and at different strain rates. Density distribution and the location of maximum and minimal density zones were predicted using DEFORM 2D, a programme based on FEA. The damage mechanism that controls the process of densification was established, and the essential value of damage was found.

I. Cristofolini, G. Pederzini, A. Rambelli & A. Molinari [22] Studies were carried out the behaviour of austenitic stainless steel powder column during uniaxial cold compaction. In a hydraulic press, powders of different particle sizes were compacted to the same green density, thus having different H/D ratios to account for geometry’s effect. By evaluating the data continuously reported by the press, the contribution of reversible phenomena (elastic deformation of powders and tools) and irreversible phenomena (rearrangement and plastic deformation of powders) was distinguishable. An empirical model for densification was proposed, taking into account both density and density changes versus the pressure applied. It analyzed the pattern of reversible and permanent deformations against the applied strain, while proposing an empirical model. The relation between the densification curves and the permanent deformation curves made it possible to illustrate the physical significance of the model that defines the increase in density for the different particle size.

CONCLUSION:-

Pure aluminium mixed with various reinforcements through powder metallurgy fabrication technique improves density it will results in better mechanical properties.

REFERENCES:-

[1] K. R. VENKATACHARI and R. RAJ, “Shear Deformation and Densification of Powder Compacts,” *J. Am. Ceram. Soc.*, vol. 69, no. 6, pp. 499–506, 1986, doi: 10.1111/j.1151-2916.1986.tb07452.x.

[2] R. Narayanasamy and K. S. Pandey, “Salient features in the cold upset-forming of sintered aluminium-3.5% alumina powder composite preforms,” *J. Mater. Process. Technol.*, vol. 72, no. 2, pp. 201–207, 1997, doi: 10.1016/S0924-0136(97)00169-6.

[3] R. Narayanasamy, T. Ramesh, and K. S. Pandey, “Some aspects on strain hardening behaviour in three dimensions of aluminium-iron powder metallurgy composite during cold upsetting,” *Mater. Des.*, vol. 27, no. 8, pp. 640–650, 2006, doi: 10.1016/j.matdes.2004.12.012.

[4] R. Narayanasamy, T. Ramesh, and K. S. Pandey, “An experimental investigation on strain hardening behaviour of aluminium - 3.5% alumina powder metallurgy composite preform under various stress states during cold upset forming,” *Mater. Des.*, vol. 28, no. 4, pp. 1211–1223, 2007, doi: 10.1016/j.matdes.2006.01.010.

[5] R. Narayanasamy, T. Ramesh, and K. S. Pandey, “Some aspects on cold forging of aluminium-alumina powder metallurgy composite under triaxial stress state condition,” *Mater. Des.*, vol. 29, no. 6, pp. 1212–1227, 2008, doi: 10.1016/j.matdes.2006.07.012.

[6] R. Narayanasamy, V. Anandakrishnan, and K. S. Pandey, “Effect of geometric work-hardening and matrix work-hardening on workability and densification of aluminium-3.5% alumina composite during cold upsetting,” *Mater. Des.*, vol. 29, no. 8, pp. 1582–1599, 2008, doi: 10.1016/j.matdes.2007.11.006.

[7] R. Narayanasamy, T. Ramesh, K. S. Pandey, and S. K. Pandey, “Effect of particle size on new constitutive relationship of aluminium-iron powder metallurgy composite during cold upsetting,” *Mater. Des.*, vol. 29, no. 5, pp. 1011–1026, 2008, doi: 10.1016/j.matdes.2006.06.004.

[8] R. Narayanasamy and K. S. Pandey, “Some aspects of work hardening in sintered aluminium-iron composite preforms during cold axial forming,” *J. Mater. Process. Technol.*, vol. 84, no. 1–3, pp. 136–142, 1998, doi: 10.1016/S0924-0136(98)00088-0.

[9] R. Narayanasamy, T. Ramesh, and K. S. Pandey, “Some aspects on cold forging of aluminium-iron powder metallurgy composite under triaxial stress state condition,” *Mater. Des.*, vol. 29, no. 4, pp. 891–903, 2008, doi: 10.1016/j.matdes.2006.05.005.

[10] B. G. K. S. M. S. B. B. J. J. Hussain, “Densification of W-brass Composites by Infiltration,” *Int. J. Sci. Res.*, vol. 4, no. 3, pp. 72–75, 2015, [Online]. Available: https://www.ijsr.net/archive/v4i3/SUB151893.pdf.

[11] A. Molinari, I. Cristofolini, G. Pederzini, and A. Rambelli, “A densification equation derived from the stress-deformation analysis of uniaxial cold compaction of metal powder mixes,” *Powder Metall.*, vol. 61, no. 3, pp. 210–218, 2018, doi: 10.1080/00325899.2018.1466501.

[12] S. M. Y. Kaku, A. K. Khanra, and M. J. Davidson, “Strain Hardening Behaviour and Its Effect on Properties of ZrB2 Reinforced Al Composite Prepared by Powder Metallurgy Technique,” *J. Inst. Eng. Ser. D*, vol. 99, no. 1, pp. 115–124, 2018, doi: 10.1007/s40033-018-0155-6.

[13] S. M. Yadav Kaku, A. K. Khanra, and M. J. Davidson, “Effect of deformation on densification and corrosion behavior of Al-ZrB2 composite,” *Metall. Mater. Eng.*, vol. 23, no. 1, pp. 47–63, 2017, doi: 10.30544/264.

[14] S. Tiwari, P. Rajput, and S. Srivastava, “Densification Behaviour in the Fabrication of Al-Fe Metal Matrix Composite Using Powder Metallurgy Route,” *ISRN Metall.*, vol. 2012, pp. 1–8, 2012, doi: 10.5402/2012/195654.

[15] O. F. Mechanical, “IJMET © I A E M E,” pp. 1–7, 2013.

[16] R. Ananthanarayanan, N. S. Rai, M. Chand, N. Prasad, R. Ram, and M. Naicker, “Densification behaviour of sintered-forged aluminium composite preforms,” *Proc. Inst. Mech. Eng. Part B J. Eng. Manuf.*, vol. 228, no. 3, pp. 441–449, 2014, doi: 10.1177/0954405413501811.

[17] B. Chaitanya, C. Venkatesh, G. Suresh, and K. S. M. Yadav, “Effect of Deformation on the properties of Al-4Cu-0.5Mg-2SiC Powder Metallurgy Composite,” *Int. J. Civil, Mech. Energy Sci.*, vol. 3, no. 6, pp. 218–221, 2017, doi: 10.24001/ijcmes.3.6.1.

[18] K. C. B, “Properties Evaluation of Al-Sic Powder Metallurgy Preforms,” vol. 6, no. 2, pp. 729–732, 2018.

[19] S. M. Y. Kaku, A. K. Khanra, and M. J. Davidson, “Effect of deformation on properties of Al/Al-alloy ZrB2 powder metallurgy composite,” *J. Alloys Compd.*, vol. 747, pp. 666–675, 2018, doi: 10.1016/j.jallcom.2018.03.088.

[20] R. Narayanasamy, T. Ramesh, and K. S. Pandey, “Workability studies on cold upsetting of Al-Al2O3 composite material,” *Mater. Des.*, vol. 27, no. 7, pp. 566–575, 2006, doi: 10.1016/j.matdes.2004.12.005.

[21] M. Ahasan and M. J. Davidson, “Modeling Aspects of Hot Densification and Deformation Studies on Al-TiB2 Composite Preforms,” *Mater. Manuf. Process.*, vol. 30, no. 10, pp. 1190–1195, 2015, doi: 10.1080/10426914.2015.1019099.

[22] I. Cristofolini, G. Pederzini, A. Rambelli, and A. Molinari, “Densification and deformation during uniaxial cold compaction of stainless steel powder with different particle size,” *Powder Metall.*, vol. 59, no. 1, pp. 73–84, 2016, doi: 10.1080/00325899.2015.1114747.