Region Growth Based Segmentation to Improve the Porosity of Cu - (5–20%) W Composite Preforms

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Abstract

While preparing the composite preform in the powder metallurgy Lab, the various defects due to porosity, open crack and residual stresses are possible. This may lead to poor life and strength of materials. It is difficult to predict the defects in the form of pores physically in the powder metallurgy Lab. To simplify this kind of problem, the Scanning Electron Microscope (SEM) images are generated from the powder composites and are segmented using region growth approach to find the distribution of pores. Normally, the composite preforms are being produced through various processes like mechanical milling, mixing, compaction, sintering and hot extrusion. In this study, Cu–(5–20%) W composite preforms, with a preform density of 94% are prepared. The pore size in term of coverage area, perimeter during different sintering atmospheres are derived. Further, the porosity is reduced during extrusion process. The results of SEM images are compared before and after sintering and extrusion process. This kind of work will aid the manufacturing process of material parts in predicting their strength and life time.

Keywords- Image segmentation, Region growing, composites, porosity analysis

I. INTRODUCTION

The digital image processing techniques are being applied to automate all the processes of different applications [1]. The digital images are manipulated to get more information about the properties of materials. While preparing powder composites in the Powder Metallurgy (P/M) Lab, the various detects due to porosity, open crack and residual stresses are possible, which may lead to poor life time and strength of materials. The pores are possible in various stages. This will affect the strength and lifetime of material products. It is very difficult to measure the pores physically in the Lab. To overcome these problems, the SEM images of these powder composites are generated and they are processed to calculate the distribution of pores as well as the contribution of each powder material in the powder composite. In this study the Copper–tungsten (Cu–W) composites are considered to support the manufacturing of material products since the Cu–W composites are extensively used for their superior strength at high temperature and having wear resistance for electrical discharge, electrode materials, relay blades and electrical contact supports [2].

In this study the image processing techniques are applied to study the defects of materials in the form of SEM images, since SEM is a powerful technique in the examination of materials. And also the digital image processing technique like segmentation can classify the defect areas of the materials easily. The SEM images are used widely in metallurgy, geology, biology and medicine. Also these SEM images are used to find the pores and the contribution of various materials. The material products are being manufactured through various processes like mechanical milling, mixing, compaction, sintering and hot extrusion. Cu–(5–20%) W composite preforms, with a density of 94% were prepared in the lab. The defects occurred in various stages are collected in the form of images. The pore size during different sintering atmospheres and the pore size reduction during extrusion were studied.

II. LITERATURE SURVEY

Shwetabh Singh (2013) showed that the edges obtained in the images can be used for classification of particles, determining sizes & shapes & also distinguishing particles in agglomerates more precisely[3]. Azmi Tawfik Alrawi et al. (2012) studied that the proportion of porosity on the surface of CdS thin film less in higher annealing temperature, because the annealing works on recrystallized grains of the thin film so the white areas are growing and which represents the surface of thin film and the other hand, the black areas less than which represent pores, cracks and defects on the surface of the thin membrane [4]. Meena et al. (2014) analysed SEM images with pore characteristics [5]. Azmi Tawfik Alrawi et al. (2012) obtained the proportion of porosity on the surface of CdS thin film [4] Gary Chinga (2002) used image analysis techniques to handle micro structures of paper [6]. Manuel F.M. Costa (2004) applied image processing techniques to the characterization of Nano structures [7]. M. G. Cortina-Januchs et al. (2011) detected pore space in CT soil images [8]. Aref Naimzad et al. (2014) studied comparatively on Mechanical and Magnetic properties of porous and Nonporous Film-shaped Magnetorheological Nan composites [9]. Ahmet H. Aydilek et al. (2002) measured fiber thickness and pore opening sizes in a cross-sectional image a woven geotextile. [10] Shawn Zhang, Robert E. Klimentidis et al. (2011) used image processing techniques for porosity and permeability analysis of SEM 3D images [11].

In the previous research, mostly the image processing techniques were applied to the different images other than SEM images related to the study of material properties. This approach used the SEM images to identify and rectify the defects without destructing the materials.

III. EXPERIMENTAL DETAILS

5-20% of tungsten powders were mixed with copper to prepare different categories of preforms like Cu-0W, Cu-5W,Cu-10W and Cu20W . The mixing was done using by a suitable punch and die set assembly of UTM, of 1 *MN* capacity. The composites with 20 mm diameter were prepared. Compacting pressure was applied gradually, and it was 1.2 *GPa* for all the specimens. The Graphite was used as lubricate while preparing the composites. The initial density 87% was maintained by accurately controlling the mass and observing the compacting pressure employed. After the compaction, the compacts were immediately taken out from the die set assembly and loaded into the sintering furnace for sintering. The sintering process was performed using different conditions, namely, normal atmospheric air and argon atmosphere at various sintering temperatures such as 750℃, 800℃, 850℃, for a heating period of 1 *h* using an electric muffle furnace. The sintering temperature was increased to get good bonding and the sintering temperature was randomly increased to 750℃. Again this was increased from 750℃ to 850℃ and the hardness was improved after sintering. Sintering of Cu at 850˚C under normal atmospheric conditions had the presence of large sized visible pores. Then sintered composite of Cu at 800˚C using argon atmospheric conditions produced small size visible pores . Finally the different categories of composites like Cu-0W, Cu-5W,Cu-10W and Cu20W were applied to the extrusion process for improving the hardness further.

A. Methodology Adopted

Image is a collection of signals. These signals are processed to derive meaningful information. The image is defined as a 2D functions (x, y), where x and y represents are the spatial coordinates and the amplitude off at any pair of coordinates (x,y) is called the intensity or the gray level of the image at that point or pixel [1]. It is used in various domains. The images are manipulated through various stages like Acquisition, prep-processing, image enhancement, image transformation, image segmentation, image representation and Image recognition.

The first step in image processing system is Image Acquisition, where the optimal image (real world data) is converted into array of numeric data. In the field of powder metallurgy, for collecting the images, SEM (Scanning Electron Microscope) is used. It is a type of electron microscope that produces images of a sample by scanning it with a focused beam of electrons. The electrons interact with atoms in the sample, producing various signals that can be detected and that contain information about the sample's surface topography and composition. The electron beam is generally scanned in a raster scan pattern, and the beam's position is combined with the detected signal to produce an image. SEM can achieve resolution better than 1 *nm*. Specimens can be observed in high vacuum, in low vacuum, in dry conditions (in environmental SEM), and at a wide range of cryogenic or elevated temperatures. The images are stored in gif format.

In image processing, segmentation is the core stage used to partition the image into various parts with respect to their similarity. Segmentation is the process of extracting points, lines or regions, which are then used as inputs for complementary tasks such as registration. Segmentation falls into two categories intensity based segmentation and region based segmentation. The region based segmentation is a technique in which segmentation is carried out based on the similarities in the given region. Region growing is a classification of region based segmentation. As the name implies, region growing is a procedure in which pixels are grouped based on some predefined condition. It is a pixel-based image segmentation using initial seed points to identify the regions of images. This method examines neighboring pixels of initial seed points and determines whether the pixel neighbors should be added to the region. The process is iterated until the sufficient regions are identified. The initial region begins as the exact location of these seeds. Region growing methods can provide the original images which have clear edges with good segmentation results. The SEM images are generated for the Cu–(5–20%) W composite preforms before and after sintering process. The SIPNC_Cu_W Algorithm (SEM IMAGE POROSITY for nano composite of type: Copper–tungsten) is used to determine the porosity and its characteristics.

B. Algorithm SIPNC_Cu_W

1) For each core process like sintering / extrusion of Manufacturing Department
   - Capture the SEM image at the starting of the process
   - Applied to image processing
   - Reading and Resizing the image
   - Removing noise of Image
   - Enhancing the images
2) Apply region – based segmentation
   - Pick up an arbitrary point(x,y) of the image as seed

– Consider the neighbours of seed point using 4 or 8 connected method
– Check each neighbouring pixel whether it is in the same region as (x,y)
– Accept the neighbouring pixel if it satisfies the homogeneity property of a region.
– Once the newly accepted is assigned into the region, its neighbours are checked using 4 or 8 connected method.
– The segmentation is repeated until no more new pixels.
– Finally the labels are assigned for each region

3) Calculate the number of regions of an Image, total area and total perimeter of the image. Also predict the texture properties such as average intensity, average contrast and entropy information of an image.
4) If the pore size is larger, the sintering process is repeated with updated temperature.
5) For the resultant powder composite the image is generated and the above steps are repeated until the pore size gets reduced.

Further the pore sizes are recued further using extrusion process. The intensity of seed point and the threshold values are reported in Table 3 for the SEM images acquired before / after the sintering and extrusion processes.

IV. RESULTS AND DISCUSSION

Figure 1 shows the composite preforms after sintering. Fig. 2(a) shows the SEM image of the sintering of Cu at 850˚C under normal atmospheric conditions. It reveals the presence of large sized visible pores. However, Fig. 2(b) shows the SEM image of sintered composite of Cu at 800˚C using argon atmospheric conditions. It reveals the presence of small size visible pores as compared to the atmospheric condition. Further, Fig. 3 shows the source images of Cu composites and the respective segmented images before / after sintering. The raw and segmented images of Cu-5W before and after sintering are shown in Fig. 4 and source and segmented images of Cu-20W before and after sintering are shown in Fig.5. Table 1 reports the measurements of pores of various composites before and after sintering. It seems that the pore area and perimeter has been reduced after sintering process of all Copper–tungsten (Cu–W) types. Similarly the source and segmented images generated during the extrusion process of the composite preforms of Cu-0W, Cu-5W,Cu-10W and Cu20W are exhibited in Fig.6,7 and 8 respectively. Table 2 summarized the pore properties of SEM images of before and after extrusion process. The intensity of seed and threshold used during region growing are reported in Table-3.

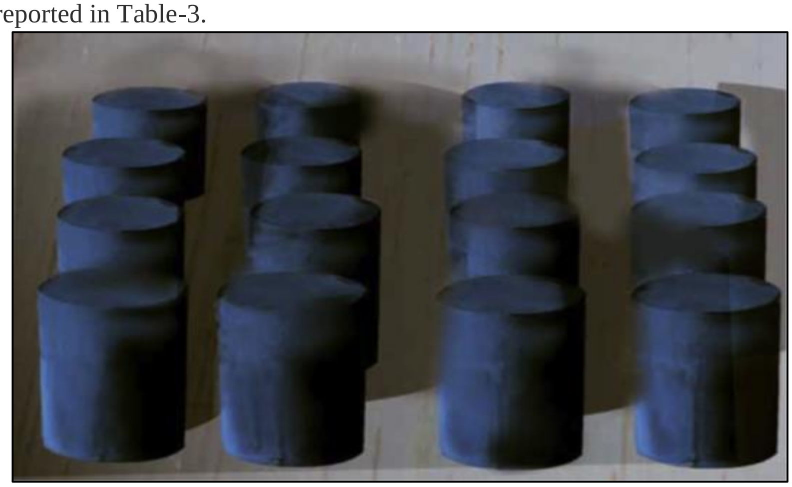

Fig. 1: Sintered preforms

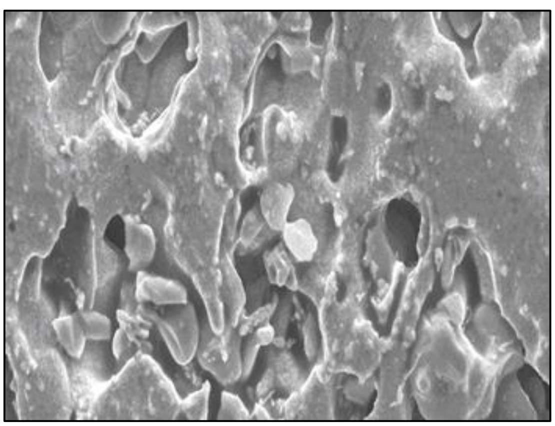

Fig. 2: (a) SEM image generated during sintering at Normal atmosphere (850˚C)

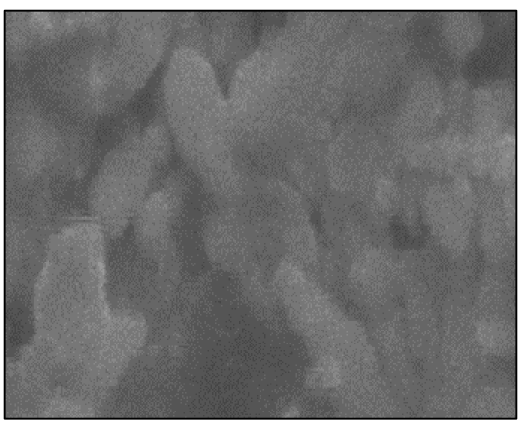

Fig. 2: (b) SEM image generated during sintering at argon atmosphere (800˚C)

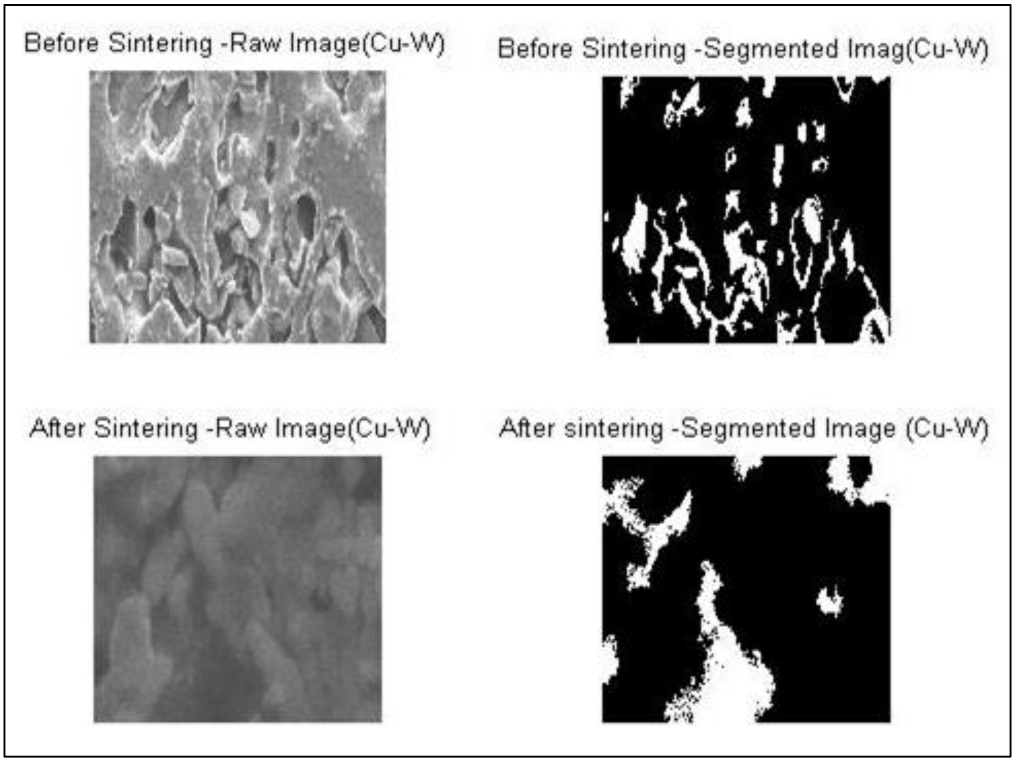

Fig. 3: Raw and segmented images of Cu –W composite before and after sintering

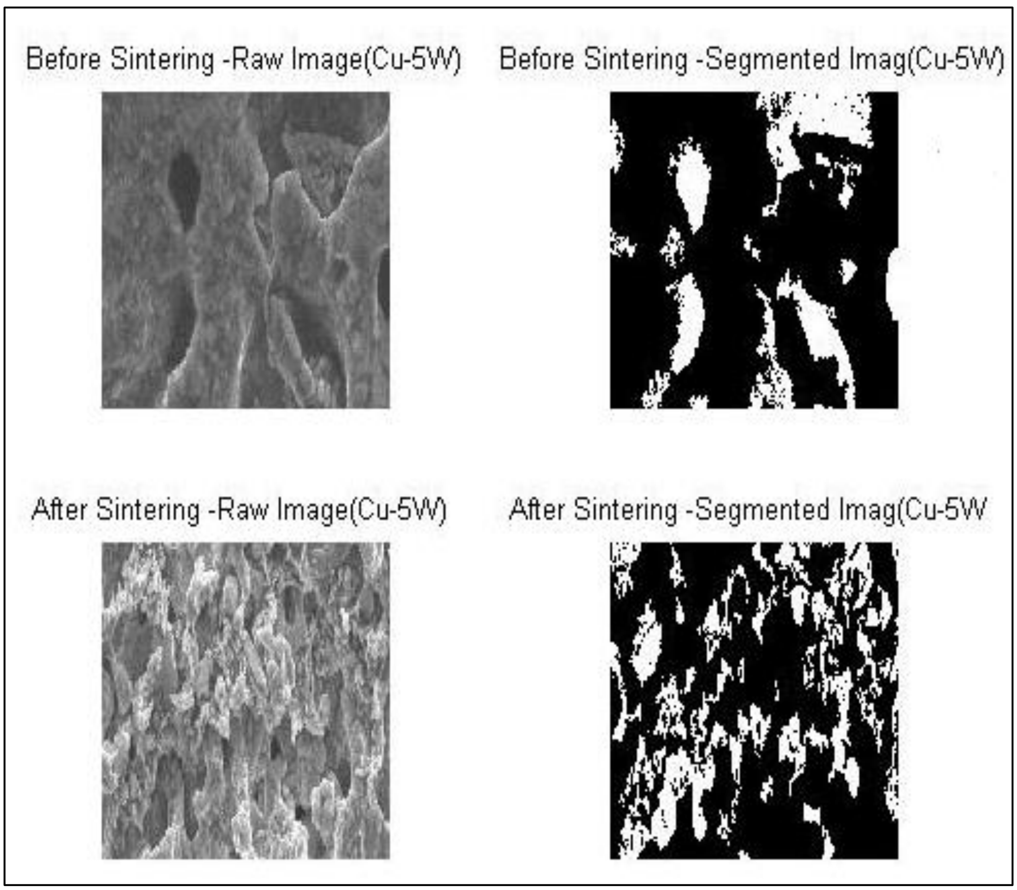

Fig. 4: Raw & segmented images of Cu –5W composite before and after sintering

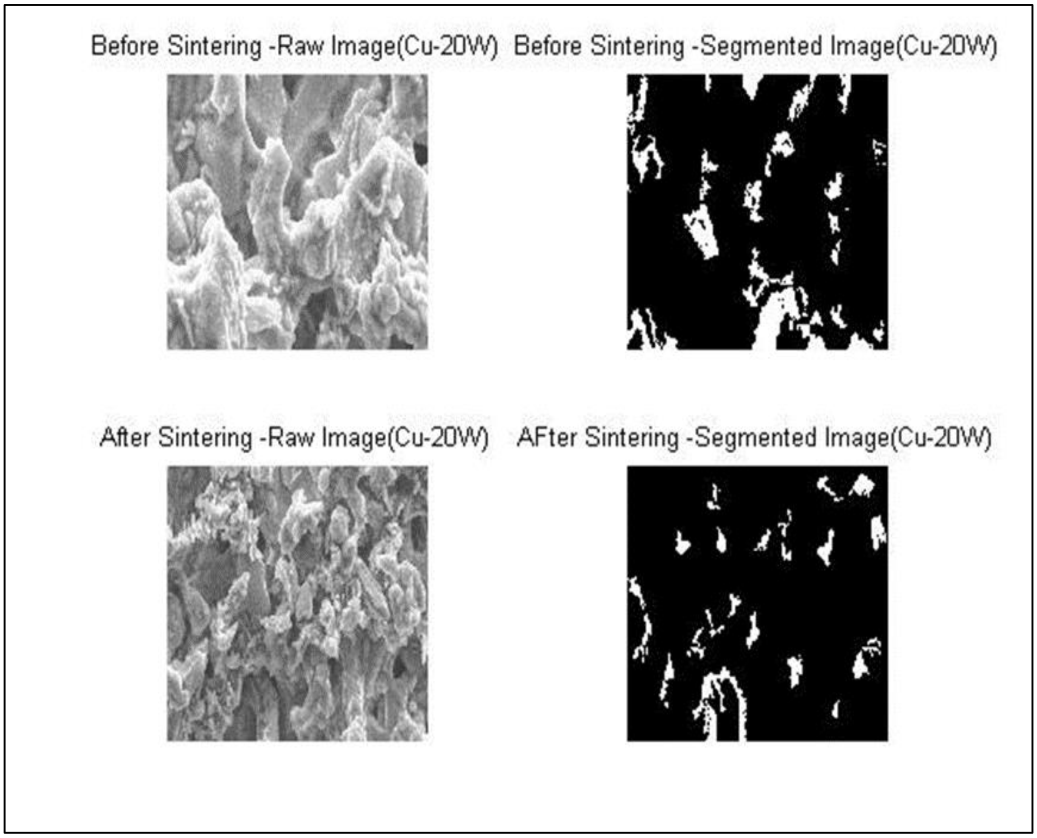

Fig. 5: Raw & segmented images of Cu-20W composite before sintering and after sintering

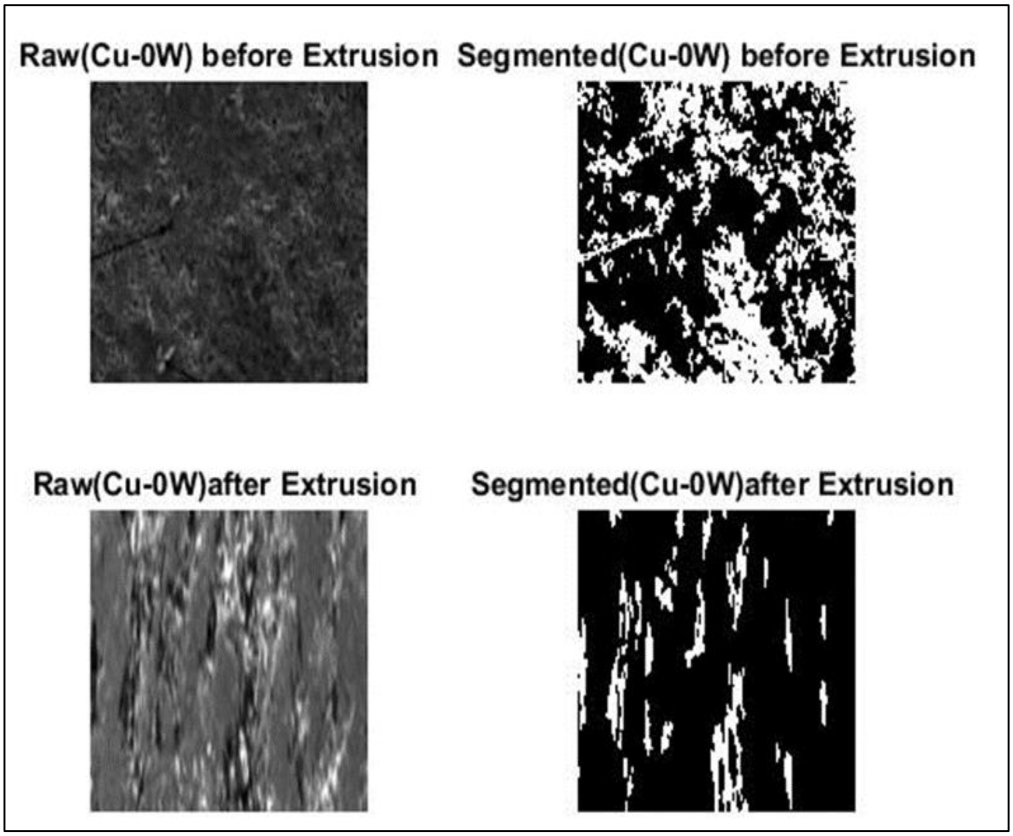

Fig. 6: Raw & segmented images of Cu-W composite before and after Extrusion

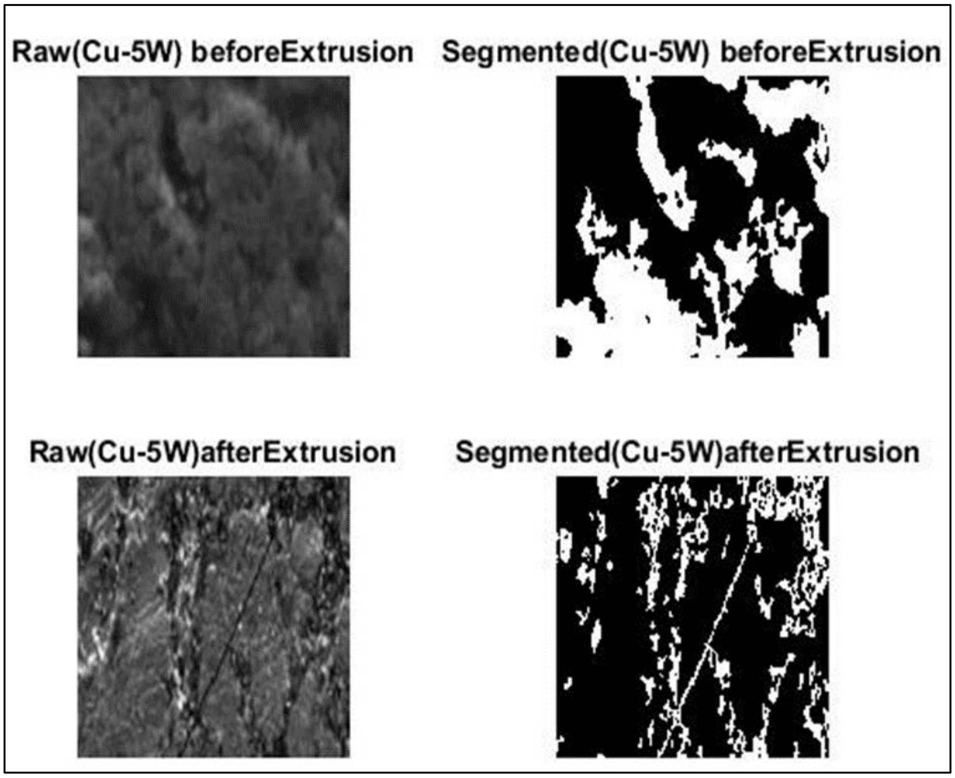

Fig. 7: Raw & Segmented images of Cu-5W composite before and after Extrusion

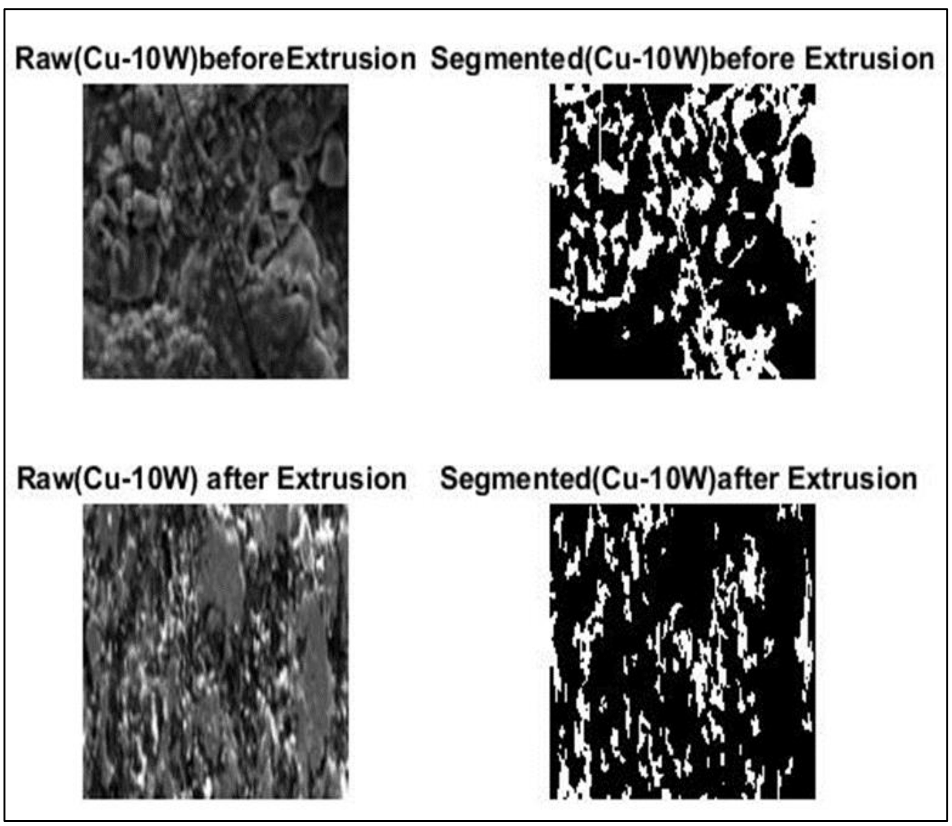

Fig. 8: Raw & Segmented images of Cu-10W composite before and after extrusion

Table 1: Cu-W nano composites at room and argon atmosphere

Region Property	*Sintering at normal atmosphere (850°C)*	*Sintering at argon atmosphere (800°C)*
No. of regions	*42*	*6*
Area	*38764*	*33828*

Perimeter	10007	5676.6
Texture properties – Average Intensity – Average contrast – R – Third Moment – Uniformity	39.5393 92.2993 0.1158 23.0481 0.7380	43.2439 95.6931 0.1234 23.7308 0.7183
Entropy Source Image Entropy Segmented Image	7.0296 0.6223	5.6588 0.6568
Nano Composite Cu-5W		
No. of regions	20	29
Area	49029	9271
Perimeter	8911.8	4513.8
Texture properties – Average Intensity – Average contrast – R – Third Moment – Uniformity	50.0096 101.2496 0.1362 24.4334 0.6847	59.1026 107.6013 0.1511 24.3570 0.6439
Entropy Source Image Entropy Segmented Image	6.2649 0.7141	7.1907 0.7811
Nano Composite Cu-20W		
No. of regions	26	22
Area	30931	17818
Perimeter	7449.3	11337
Texture properties – Average Intensity – Average contrast – R – Third Moment – Uniformity	31.5496 83.9629 0.0978 20.8052 0.7832	42.1617 94.7292 0.1213 23.5538 0.7240
Entropy Source Image Entropy Segmented Image	7.2848 0.5400	7.2744 0.6469

Table -2 Composites Before or after extrusion

Nano Composite Cu-W		
Region Property	Before Extrusion	After Extrusion
No. of regions	112	31
Area	172781	52882
Perimeter	26003.13	9784.254
Texture properties – Average Intensity – Average contrast – R – Third Moment – Uniformity	89.3071 121.645 0.18538 17.3829 0.54487	27.12996 78.62636 0.086819 19.08491 0.809855
Entropy Source Image Entropy Segmented Image	5.85128 0.934268	6.865375 0.488936
Nano Composite Cu-5W		
No. f regions	8	64
Area	187629	92920
Perimeter	69767	11231
Texture properties – Average Intensity – Average contrast – R – Third Moment – Uniformity	97.66092 123.9592 0.19114 14.10238 0.527385	48.22764 99.86062 0.132967 24.3142 0.693283
Entropy Source Image Entropy Segmented Image	5.988404 0.960122	6.883518 0.699644
Nano Composite Cu-10W		
No. of regions	37	81
Area	139370	84253
Perimeter	16959	16456

Texture properties – *Average Intensity* – *Average contrast* – *R* – *Third Moment* – *Uniformity*	*72.52929* *115.0412* *0.16911* *22.37626* *0.592942*	*43.84595* *96.2198* *0.124634* *23.8213* *0.71524*
Entropy Source Image *Entropy Segmented Image*	*6.85311* *0.861415*	*7.357052* *0.662135*
Nano Composite Cu-20W		
No. of regions	*15*	*22*
Area	*151275*	*49024*
Perimeter	*8207.9*	*6247.5*
Texture properties – *Average Intensity* – *Average contrast* – *R* – *Third Moment* – *Uniformity*	*78.72474* *117.8016* *0.175879* *20.81861* *0.573173*	*25.51249* *76.51665* *0.082602* *18.36574* *0.819922*
Entropy Source Image *Entropy Segmented Image*	*6.886508* *0.891696*	*7.540112* *0.469*

Table 3: Intensity of seed and threshold during region growing

S.No	*Type*	*Before sintering*	*After sintering*
	Cu-0W	*97, 27*	*73, 20*
	Cu-5W	*72, 21*	*84, 32*
	Cu-20W	*100, 30*	*70, 25*
	Cu-0W	*30, 15*	*40, 30*
	Cu-5W	*35, 20*	*35, 20*
	Cu-10W	*20, 20*	*20, 20*
	Cu-20W	*20, 20*	*55, 20*

V. CONCLUSION

The pore area detection and rectification is a major task in the manufacturing section of mechanical products. This region based segmentation mentioned in this paper helps to identify the pore areas of Cu-W composites without destructing the materials. The SEM image based Analysis is helpful to detect the morphological characteristics of material defects. . Further the soft computing approach like Genetic algorithm may be applied to identify the optimal features of SEM images while characterizing the composites in the manufacturing section of mechanical parts in future.

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