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Evaluation of Strength and Study of Fracture behaviour of Silicon Carbide Reinforced Aluminium 2024 Metal Matrix Composite using Machine Vision Technique

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ABSTRACT: Metal Matrix composites (MMCs) are most promising materials in recent time to meet the demands of rapid growth in technology in the field of aerospace and automobile applications hence there is a need to develop high strength MMCs. Strength of MMCs can be enhanced by using suitable reinforcement. Crack formation, propagation and fracture behaviour of a material is depends on strength so by analysing the surface fracture behaviour, strength of composite material can be evaluated indirectly at macro level using Machine Vision technique. In this dissertation work, the varying percentage of Silicon carbide (SiC) reinforced Al2024 MMC is fabricated using stir casting method and its strength is evaluated by studying its fracture behaviour using Machine Vision technique. Composite material is subjected to online inspection under tensile loading by video recording of crack formation and its growth using suitable lighting and a digital camera. Image frames are extracted from video recorded and images are processed to reduce noise and enhance its quality. The edges of the processed image are extracted to visualize the neck formation and crack. The fracture behaviour is studied by analyzing neck formation radius and crack length of MMC of varying reinforcement composition.

KEYWORDS: Metal Matrix composites (MMCs), Al2024 alloy, Silicon Carbide (SiC) reinforcement, Stir casting, Machine Vision technique.

I. INTRODUCTION

Rapid growth of technological changes in the industry demands materials with extra and unusual combination of properties that cannot be obtained in the conventional monolithic metal alloys, ceramic materials or polymers. This is mainly true for the materials that are required for aerospace, transportation and automobile Applications. It is therefore need to develop composite materials having desirable properties like high strength with low density, low weight, high stiffness, corrosion resistance and hardness. It has been seen from literature survey that strength can be enhanced with the suitable reinforcement composition [7-11]. Aluminium Metal Matrix Composites are one such good option which can yield desirable properties. More work has taken place in field of Metal Matrix Composite (MMC) the result of which has shown enhancing its properties by adding suitable reinforcement. Crack formation, propagation and fracture behaviour of a material is depends on strength so by analysing the surface fracture behaviour, strength of composite material can be evaluated indirectly at macro level. The irregularity of crack shape and difficulty of measuring crack dimension online during testing demands new technology.

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With the advantages of high speed, good accuracy and flexibility Machine Vision and image processing technique has become more attractive and popular in the field of manufacturing for measurement and to inspect surface defects and cracks[1-2]. While human workers need to inspect part to check the quality, Machine Vision system uses image processing software to perform similar inspection. Machine vision helps in achieving 100% quality control in manufacturing field by reducing cost, time and ensures high level of customer satisfaction.

Machine Vision system combines both image acquisition and image processing system with digital input and output devices and computer networks to drive quality control system. Machine vision and image processing technique include both hardware and software components. Camera, lens and light source are hardware components and software used to process the image.

II. METHODOLOGY

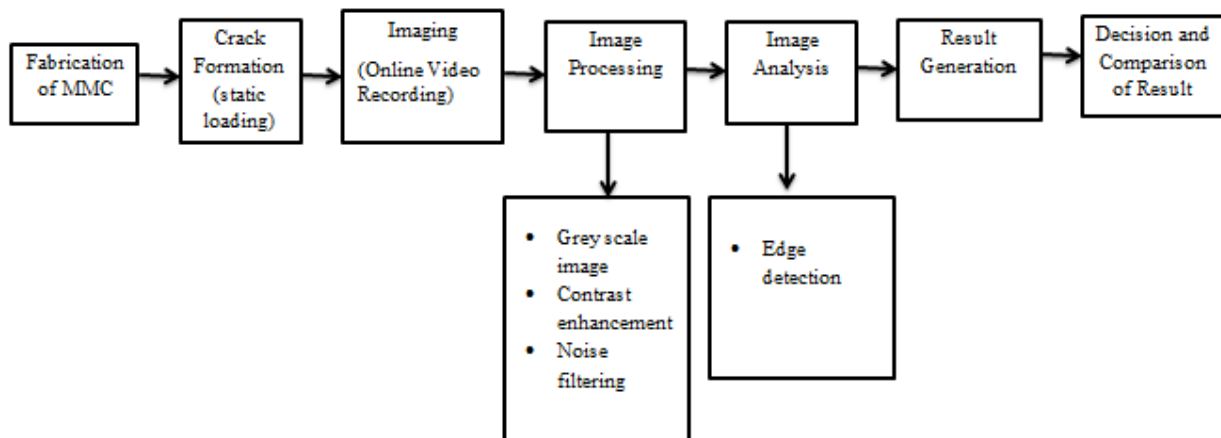


Fig.1 Block Diagram of the Methodology

Varying percentage of Silicon Carbide reinforced Aluminium Metal Matrix Composite is fabricated using Stir Casting method. Casted specimen is then machined to standard ASTM E8M dimension to conduct tensile test. A proper lighting and image acquisition system is used to record crack formation and its growth under loading. Image frames are then extracted from video recorded and are converted to grey scale image. The image is then subjected to noise filtration to remove unwanted edges and then contrast is enhanced to get clear image. Processed image is then Analysed using Edge detection method to visualise crack and neck formation. Fig.1 shows the block diagram of the proposed system.

III. EXPERIMENTATION

Stir casting method: Stir casting is the simple liquid state fabrication method of fabricating MMCs. Reinforced material is mixed with the molten matrix material using mechanical stirring for proper distribution of reinforcing particles, and then this mixture is poured into standard dies and allowed to solidify. In this process we have used Aluminium 2024 alloy as Matrix material and Silicon Carbide as reinforcing material. Specimen 1 (Al2024 alloy), Specimen 2 (Al 2024 alloy+2%SiC), Specimen 3(Al 2024 alloy+4%SiC), Specimen 4(Al 2024 alloy+8%SiC) is fabricated.

Tensile test: Tensile test is conducted to determine Ultimate Strength (UTS). A specimen with standard shape and size according to ASTM is subjected to increasing uni-axial tensile load until failure, observations are made on the elongation and load applied on the specimen. This operation is done by gripping opposite ends of the work piece in a

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tensometer and pulling it, which results in elongation of test specimen. The ultimate tensile strength tests were done in accordance with ASTM E8M standards.

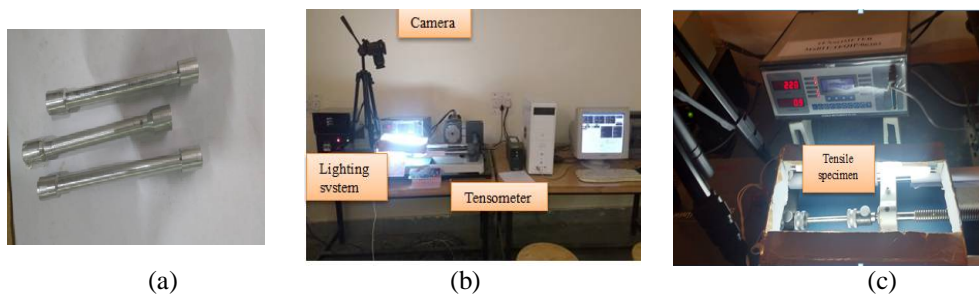


Fig.2 (a) tensile test specimens (b) Front view showing experimentation setup of camera and lighting system (c) Top view showing tensile specimen

Image acquisition : Image acquisition is the first step in Machine Vision technique. Image acquisition system includes capturing of image with proper lighting system. Input to the image processing is image so it is required to capture good quality of image to get accurate result. Proper lighting types and resolution of camera and its position enhances the quality of the image. Light and camera setup are shown in Fig.2 (b). video of tensile test is recorded online then images are extracted using suitable tool then processed to extract crack and neck formation.

Image processing: Image processing is a method to perform some operations on images in order to get an enhanced image or to extract some useful information from it. Firstly image is converted into grey scale and unnecessary information's are removed by using shen filters. Matrox Imaging Library (MIL) software is utilised for processing and analysing image.

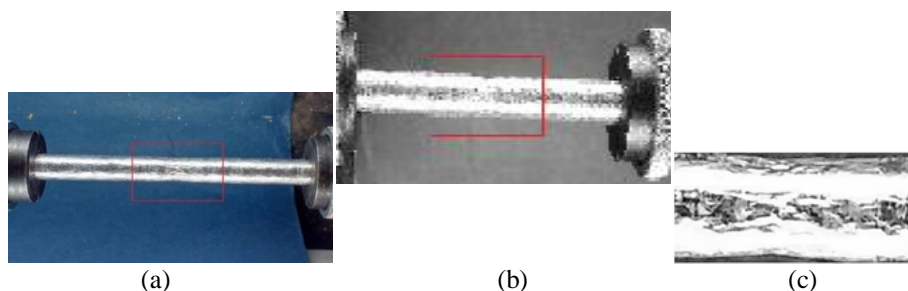


Fig.3 (a) colour image of tensile specimen showing Region of Interest(ROI) (b) Grey scale image of tensile specimen showing ROI (c) Contrast enhanced image of ROI.

Image analysis : Image analysis is the extraction of meaningful information from the processed images. Image analysis involves processing an image into fundamental components in order to extract statistical data. Edge detection is done to visualise crack and neck formation. Crack length and neck radius is calculated for all the specimens.

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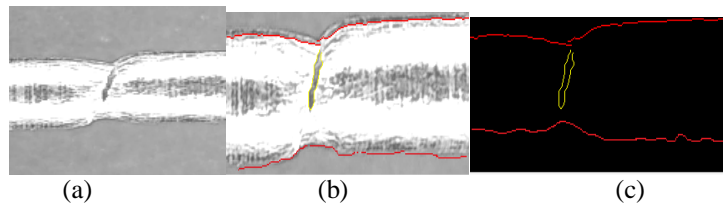


Fig.4 Image showing crack and neck formation (a) Grey scale image before edge detection (b) Edge detected image without overlay (c) Edge detected image with overlay

IV. RESULTS

Table 1: Result table of tensile test

Specimen composition	Al 2024 alloy	2% SiC-Al 2024 composite	4% SiC-Al 2024 composite	8% SiC-Al 2024 composite
Peak load (N)	7365.1	7894.6	8355.6	12827.6
Break load, (N)	725.7	186.3	39.2	19.6
Eng. UTS (N/sq. mm)	115.7	124.0	131.3	201.6
True UTS (N/sq. mm)	128.2	143.5	145.1	215.5

Table 1 shows the tensile strength of Al 2024 based composites. In these composites there is a considerable increase of tensile strength as the percentage of reinforcement increases. The increase of tensile strength is due to the increased area of bonding at the interfacial region of the matrix and the reinforcement. It is seen that the UTS of the composites increase as the reinforcement content is increased. Increase in addition of reinforcement causes reduction in the inter-spacial distance between them, which cause an increase in the dislocation pile-up. Random distribution of the particulate in the matrix restrict the plastic flow, thereby providing strength to composites.

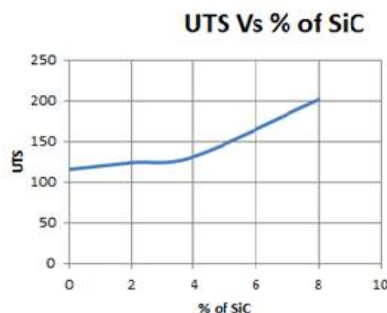


Fig.5 Ultimate tensile strength versus % of SiC reinforcement in Al2024 alloy

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The graphs showing the effect of particulate addition on UTS of the composites is presented in Fig.5. It is observed that the UTS of the composites monotonically increase as the particulate content is increased.



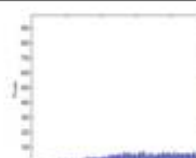
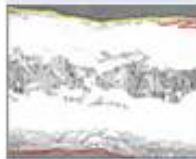

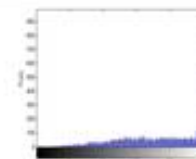
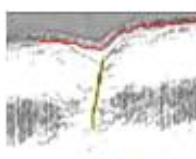

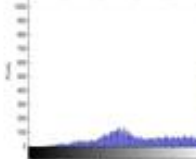
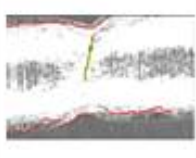

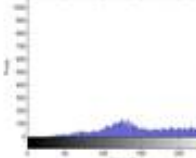
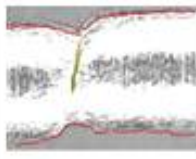
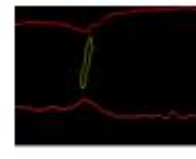
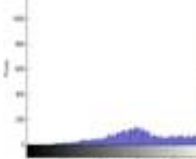

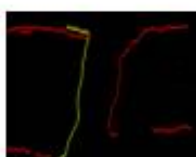
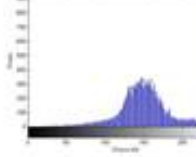
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2				0	954.12
3				96.09	749.72
4				96.72	319.80
5				96.81	253.80
6				110	-

Fig.6 Image analysis result of Aluminium 2024 alloy

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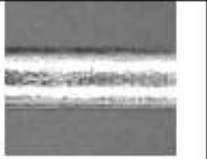


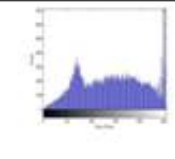
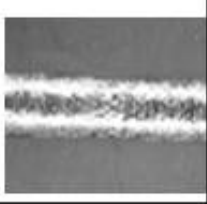
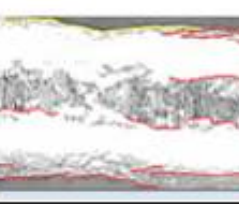

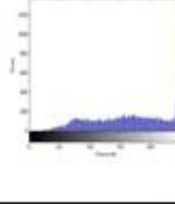

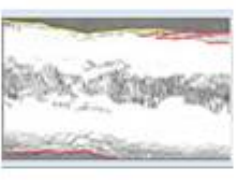

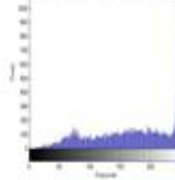
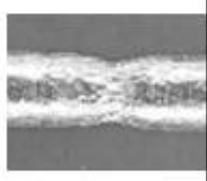
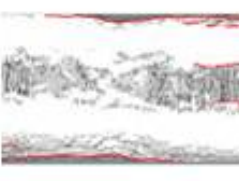

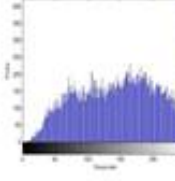
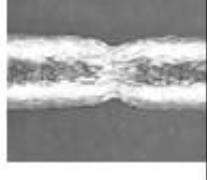
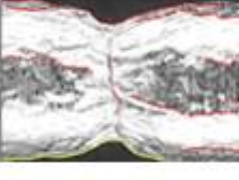
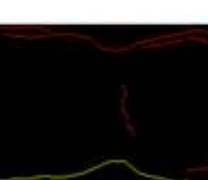
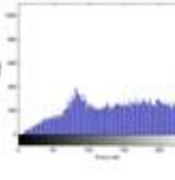

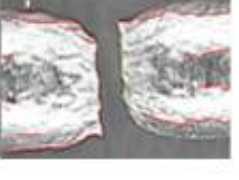

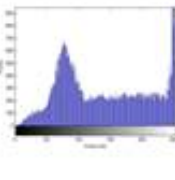
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2					1165.7
3					1055.8
4					780.5
5					388.01
6					--

Fig.7 Image analysis result of 2% SiC reinforced Aluminium 2024 Composite

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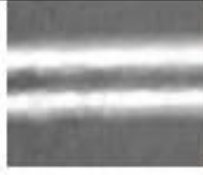
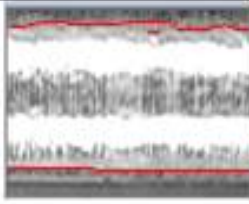

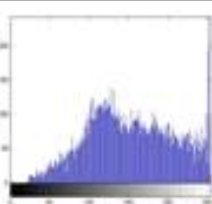
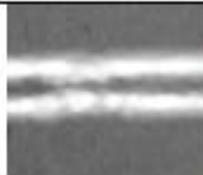
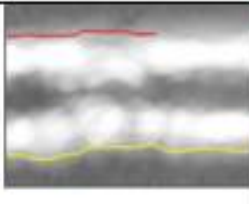
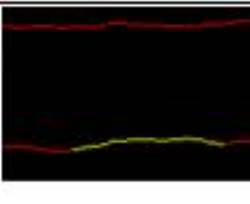
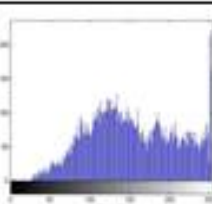

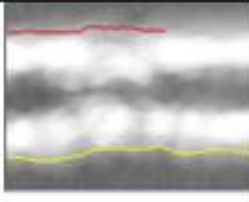
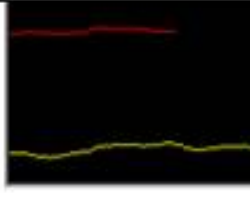
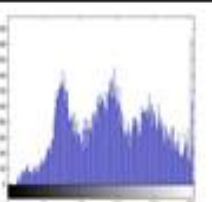

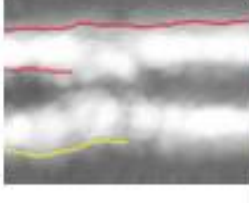
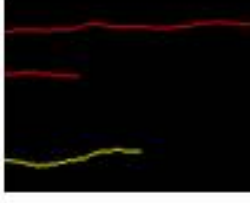
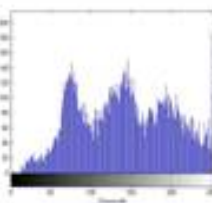
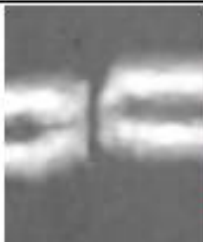


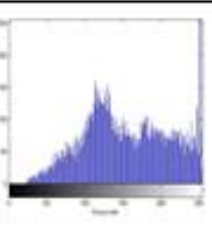
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4					362.24
5					-

Fig.8 Image analysis result of 4% SiC reinforced Aluminium 2024 Composite

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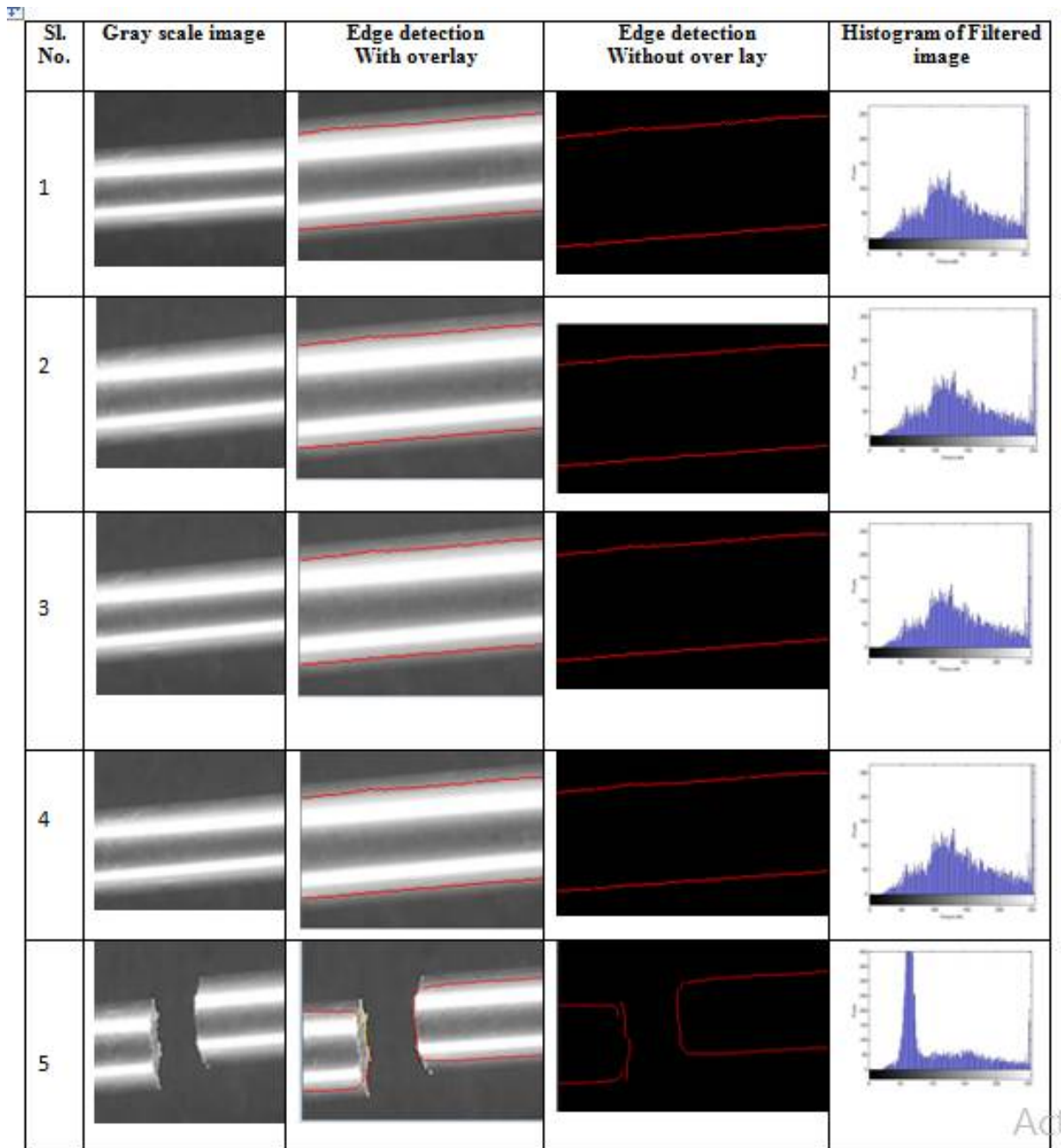


Fig.9 Image analysis result of 8% SiC reinforced Aluminium 2024 Composite

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By image analysis it is observed that,

Al 2024 is ductile in nature, fracture occurred after appreciable amount of plastic deformation. It occurs. When the load reaches 7365.1 N, it is preceded by a localized reduction in cross sectional area called necking. After which load starts decreasing with rapid growth in displacement. Final failure involves rapid crack propagation at about 45° to the tensile axis as shown in Fig.6.

Image analysis of 2%SiC-Al 2024 composite is shown in Fig.7. It withstands load about 7864.6 N which is more than Al-2024 alloy and shows less plastic deformation rate compared to Al 2024 alloy. Necking regions are analysed and it is found to be decreasing and direction of crack propagation was nearly 45° to the direction of applied tensile stress.

4%SiC-Al 2024 composite withstands load about 8355.6 N which is much more than Al-2024 alloy and shows little plastic deformation and deformation rate was moderate. Since cracks had not been seen necking regions are extracted and analysed as shown in Fig.8.

8%SiC-Al 2024 withstands high load of 12827.6N. No preceding plastic deformation is seen in this case and deformation rate was very fast. It occurs often at unpredictable levels of stress, by rapid crack propagation. The direction of crack propagation is very nearly perpendicular to the direction of applied tensile stress.

V. CONCLUSION

Metal Matrix Composite of Al-2024 reinforced with varying percentage composition of Silicon carbide was successfully casted by using stir casting method. It is concluded from tensile test that ultimate tensile strength of MMC increases with increase in percentage composition of Silicon carbide reinforcement in Aluminium 2024. A proper lighting system and image acquisition system is used successfully to conduct online inspection of fracture behaviour by recording good quality video while carrying tensile test. It is evident from image analysis that with the increase in composition of reinforcement the material exhibits brittle fracture behaviour thus losing its ductility property. This is because of locking effect of particulate reinforcement which restricts the plastic flow but it enhances load withstand capacity hence the strength.

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