TORSIONAL FATIGUE BEHAVIOUR OF ALUMINUM/COMPOSITE TUBES

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Abstract

Static and dynamic torsional behavior of composite tubes was investigated experimentally. Effects of aluminum/composite interface properties on the torsional response of composite tubes were studied. Aluminum tubes with four different surfaces were prepared: (a) no surface treatment, (b) sanded along its axis (c) knurled and, (d) holes were drilled.

1 Introduction

Due to their high specific stiffness and strength, excellent fatigue properties, corrosion resistance and increased natural bending frequencies; composites are used in many applications. One of the applications of composite tubes is using them as a driveshaft for automotive industry. Due to their increased weight metal drive shafts has to be manufactured as two parts. However composite shafts can be manufactured as one piece and power loss due to extra joints used in metal ones can be eliminated. Metal shafts have tendency to deflect due to its own weight. This can be problematic especially for extended lengths. Reinforcing metal shafts using composite inner or outer layer might improve some of the mechanical properties of metal ones [1-4]. However using hybrid approach for shafts might create some difficulties. One of the challenging difficulties is the weak interfaces between metal and composite layers. Interfacial forces between dissimilar layers are weaker compared to those between similar or same layers. When load is applied damage is first seen at interfaces. Increasing interfacial forces using some surface treatment can be a good approach for solving this problem.

In our research, hybrid aluminum/glass composite shafts were manufactured and tested. Their torsional properties were investigated. To see influence of the aluminum/composite interface properties on the torsional properties of aluminum/composite tubes; four different surface treatment on aluminum were applied (Fig.1). One aluminum was kept as purchased, second one sanded longitudinally, third one was knurled and last one was hole drilled. Then composite layer were designed using Composite Designer software. The fibers were wound on aluminum tubes at 45^{o} using filament winding machine (Fig.2). Filament winding machine was equipped with resin bath and fiber tension system as well as fiber storing shelf system.

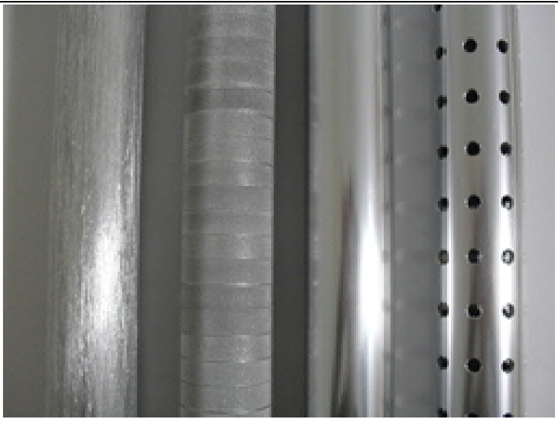


Figure 1. Treated Aluminum surfaces

Figure 2. Filament winding machine.

Following the manufacturing of tubes they were machined and sized for torsional test (Fig.3).

Figure 3. Composite test specimens

Hybrid shafts with knurled aluminum surface performed better than remaining types. Knurling aluminum surface has increased the contact area between metal and composite. Sanding aluminum has also increased the contact area but it was not as large as knurled surface. Hence hybrid tube with sanded aluminum was the second best performed tube. However drilling a hole on composite were negatively effected the performence of the tube and performance was even worse than the aluminum with no surface treatment. The initial idea of drilling hole on aluminum was having some of the matrix material diffuse in to the drilled holes. During torsion these composite extensions in the aluminum part would improve the interfacial forces and maybe did. However drilling so many holes on aluminum reduced the aluminum torsional capability and early failue of aluminum has reduced to over all performnace of hybrid aluminum composite shafts (Fig.4). Torsional fatigue tests on these tubes are currently being conducted. Aluminum tubes are exposed to cyclic torsional loading at 30, 40 and 50% of the static torsional strength. Various loading frequencies are being tested. Hybrid aluminum/composites tubes also cut at transverse direction and interfaces were examined under SEM (Fig.5). The interfaces of the sanded and no treated aluminum were quite similar but wavy structure of the sanded surface was also obvious on SEM image. Some fibers were settled at spaces between knurles but not much matrix material was seen in these spaces. However SEM image was taken from only one specimen which cut at certain location of the tube. Further invetigation will be conducted on more specimen to

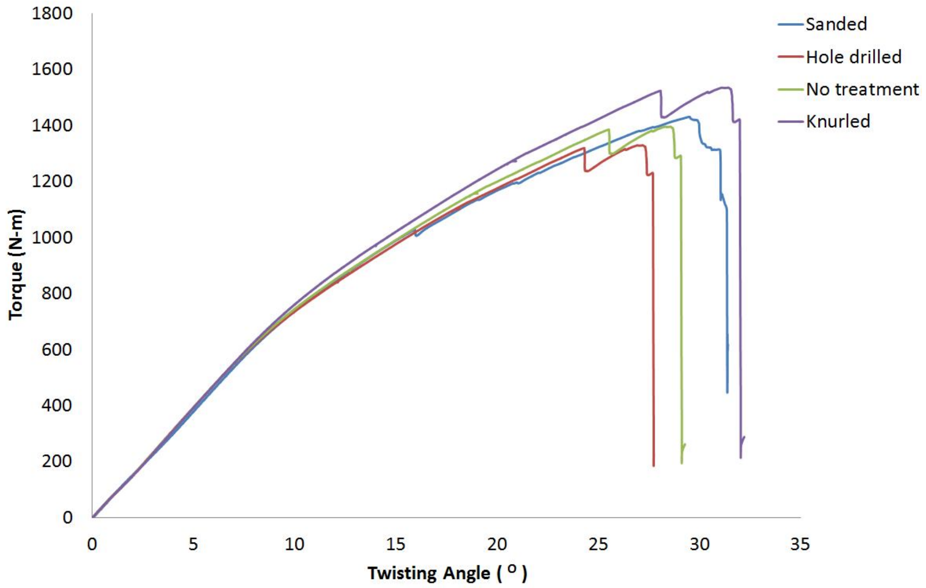
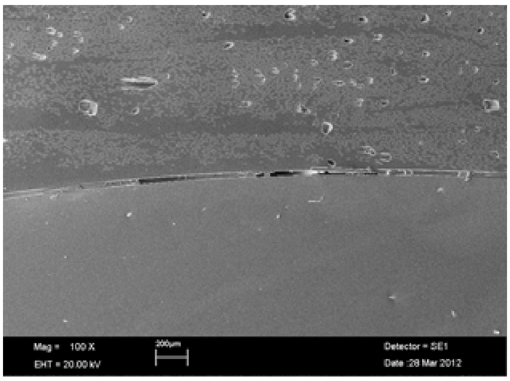
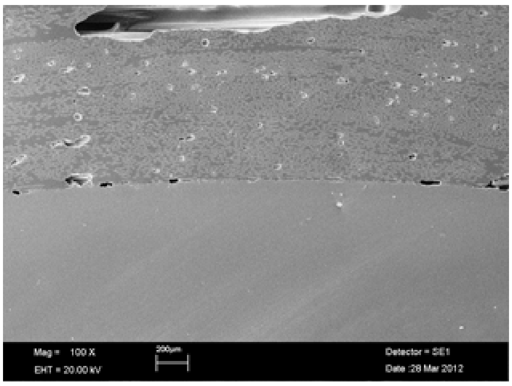


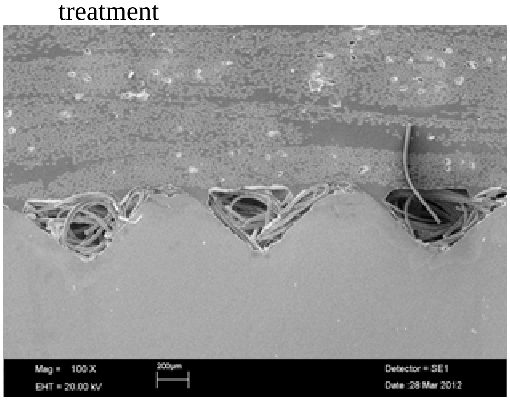
Figure 4. Torque-twisting angle relations of hybrid aluminum/composite tubes



(a) Interface of Composite/Aluminum with no treatment



(b) Interface of Composite/sanded Aluminum



(c) Interface of Composite/Knurled Aluminum

Figure 5. SEM pictures of aluminum composites (a,b and c) interfaces and composite part only (d)

2 Materials and testing methods

In this study E-Glass FWR6-1200 glass fibers were used and as a matrix material Hexion L285 Epoxy and H287 hardener were used. Glass fibers were wetted with epoxy resin in the resin bath and then wound on aluminum tubes with 35 mm diameter and 2mm mm wall thickness (Fig.6). Winding angle was $-45^o/+45^o$ for best torsional performance. 6 layers of composites were wound and total composite thickness was 3 mm and total tested diameter was 41 mm. Resin amount was arranged with the blade which is attached on the resin bath. Tension on the fibers was applied using mechanical tensioner. Manufactured composites were kept in room temperature for 20 hours and then cured at 80^oC for 15 hours.

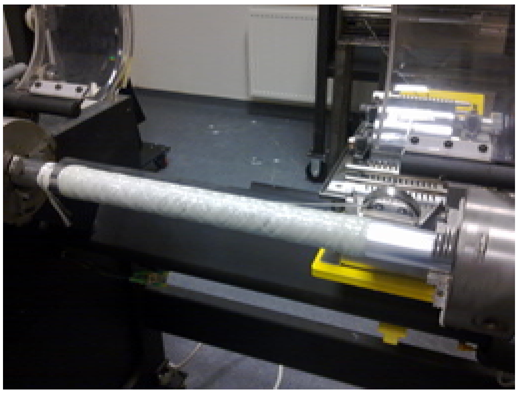


Figure 6. Manufacturing of tubes using filament winding technique

Torsion tests were conducted MTS 215 static and dynamic test machine. While the static torsional capacity of the machine was 25,000 Nm, the dynamic torsional capacity was 11,600 Nm. End-fittings for composite tubes were designed and manufactured. Two-pins were inserted at both and so torque applied by the machine can be transferred to the specimens. Some trial error procedure was used for optimum method for end fitting system which is considered one of the major problems for composite tubes.

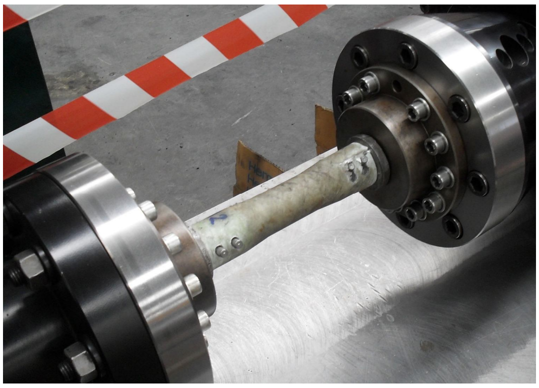


Figure 7. Torsion test of hybrid tubes

References

[1] Mutasher S.A. Prediction of the torsional strength of the hybrid aluminum/composite drive shaft. Materials and Design, 30, 215–220(2009).

[2] Khalid Y.A., Mutasher S.A., Sahari B.B., Hamouda A.M.S. Bending fatigue behavior of hybrid aluminum/composite drive shafts. Materials and Design, 28, 329–334(2007).

[3] Kim H.S., Lee D.G. Optimal design of the press fit joint for a hybrid aluminum/composite drive shaft. Composite Structures, 70, 33–47(2005).

[4] Kim H.S., Lee D.G. Design and manufacture of stainless steel/carbon epoxy hybrid shaft for cleaning large LCD glass panels. Composite Structures, 80, 279–289(2007).