Wear characteristics of Polymer Hybrid Composites manufactured by Hand layup and Vacuum bagging technique

K. V. Manjunath[1], N. Krishnamurthy[2]
[1]*Asst. Professor, Department of Mechanical Engineering*
K.S. Institute of Technology, Bengaluru, India
[2] *Professor & Head, Department of Mechanical Engineering*
Vijaya Vittala Institute of Technology, Bengaluru , India

Abstract- Natural fibre reinforced composites have already been proved to be light weight, low cost with higher strength. The composites are being globally used in all the possible fields like automobile, textile, aircraft and marine industry. Among all the available natural fibres, jute fibres are widely used due to its good mechanical properties, low cost and ease in availability. Contradictorily, aramid fibres that are manmade organic polymer have high strength with low density and are mostly used in ballistic protective applications. Hemp fibres which are plant based fibre dominate its uses in the automotive industry and textile industry due to its good abrasion resistance property. The present work is an investigation on the wear behaviour of the hybrid polymer composites. In this experimental work, three different fibres - hemp fibres, aramid fibres and jute fibres were used (in combination of one natural and other manmade) to obtain hybrid composites by two methods of fabrication – Hand layup technique and Vacuum bagging technique. Two different fibres (jute/aramid and hemp/aramid) were reinforced with epoxy matrix to fabricate fibre reinforced hybrid polymer composites (jute/aramid/epoxy and hemp/aramid/epoxy). The hybrid composites were fabricated by Hand layup technique and Vacuum bagging technique. Tribological performance of the fabricated hybrid composites in two different techniques were analysed in terms of frictional characteristics. Experimental results of wear analysis indicate vacuum bagging technique gives strong bonding strength between the fibres and the matrix and hence wear rate of the composites are low.

Keywords – Wear characteristics, Natural fibre, Hybrid composites, Epoxy.

I. INTRODUCTION

Fibre reinforced composites have recently dominated all the fields of application especially automotive, marine, military and construction industry. Polymer composites are found to be having excellent friction and wear properties with certain fillers and reinforcements. One of the important properties of polymer composites are good mechanical strength, stiffness, wear resistance and resistance to corrosion thereby making it high performance composites. Hence, composites are widely used in the industrial applications. Fibre reinforced composites already have a long history in the automotive application where Ford had fabricated an experimental car using hemp fibre in early 1940s (Mutel, 2012). This was followed by aircraft industry. Later composites became commercial in large quantities in defence industry followed by other industries like chemical plant and sports car bodies. (S.M. Saupan) Fibre reinforced composites have wide applications in automobile sector in the manufacturing of different parts of automobile such as dashboards, door panels, interiors of vehicle, and trays. The fibres have good properties of light weight, good wear resistance, and biodegradability. Hence fibres are massively used as reinforcement in various applications. Also they are used in sliding panels, bushing and bearings. In aircraft industry, composites form a major part in main landing gear doors, trailing edge panel and many more. In wind turbine, the wind turbine blades are manufactured using fibre reinforced composites. This application puts the composite materials into excessive loading conditions subjecting them to excessive wear. This brings out the importance to study and analyse the tribological performance of the composites since the performance of the material depends on the factors like reinforcement type, contact conditions, weight percentage and orientation of fibres. Many research on wear behaviour of composites have been already done but very few research on tribological behaviour of hybrid composites have been carried out.

Correa et al. found out that fibre size and types of resin affects the friction and wear behaviour of composites. The research showed the as the fibre size increased; wear resistance reduced.

Bajpai et al [2] researched on the wear and frictional study of sisal/polypropylene composite under different loads, sliding speed, and constant sliding distance thereby concluding that 30% weight of sisal fibre composite had

improved wear resistance compared to pure polypropylene. They also concluded that jute, flax and hemp fibres also exhibit similar properties. Hence, it is also shown that hybrid composites with these polymers exhibit similar property.
In the present study, two natural fibres (Hemp) and a manmade organic fibre (aramid fibre) are combined in layers to obtain hybrid composites of hemp/aramid and jute/aramid reinforced with epoxy matrix. Two methods of fabrication - one is hand layup method and the other vacuum bagging method were used to manufacture the hybrid composite specimens. Frictional and wear performance of the hybrid composites manufactured by two different techniques have been analysed with varied process parameters.

II. Experimental Work

2.1 Materials

In this study the laminates of hemp/aramid and jute/aramid fibre reinforcement were prepared with hand layup technique and vacuum bagging technique. Jute, hemp (Organic Buying Services, Faridabad, Haryana, India) and aramid fibres are supplied by Nickunj Enterprises, Mumbai, India. Epoxy resin was used as a matrix material supplied by Atul Limited, Gujarat India. Laminates were prepared using epoxy resin (Lapox L-12 provided by Atul Limited, Gujarat, India and hardener (Triethylene tetra amine provided by Atul Limited, Gujarat, India) with **10:1** by volume.

Material Properties

Table 1: Material properties

Property	Hemp fibre	Jute fibre	Aramid fibre	Epoxy
Density	0.86 g/cc	1.5 g/cc	1.47 g/cc	1.25 g/cc

.

2.2 Fabrication of composites

The aramid and jute fibres were arranged one over the other in the moulding plate with different stacking sequence. Similarly, hemp fibre and aramid fibre were arranged in different stacking sequence in the moulding plate. The fabrication was done by both hand layup technique and vacuum bagging technique. The prepared laminates are named as hemp-aramid by hand layup method as H+A-H, jute-aramid by hand layup method as J+A-H, hemp-aramid by vacuum bagging method as H+A-V and jute-aramid by vacuum bagging method as J+A-V. Specimens were later cut to the dimensions as per ASTM G99-17 standard.

2.2.1 Hand layup method

Fibres were cut to the shape and size (400 * 400) mm. First and foremost, the silica gel was applied to the inner surface in order to avoid sticking of the resin to the mould. The liquid resin was uniformly spread on the inner surface. Fibre mats were stacked alternatively within the mould cavity. Roller was used to remove any air bubbles from the mould and to maintain same thickness throughout uniformly. This is repeated until the required specification is reached. The weight percentage of reinforcement was kept constant to 25%. Table shows abbreviation for the fabricated hybrid composites.

Table 2. Abbreviation for composites along with its composition

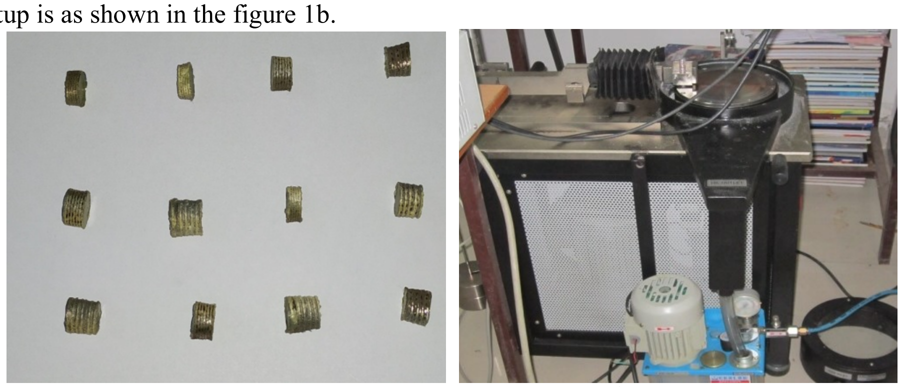
Abbreviation	Description	Composition
Hemp-Aramid with Epoxy by hand lay- up Jute-Aramid with Epoxy by hand layup Hemp-Aramid with Epoxy by vacuum bagging Jute-Aramid with Epoxy by vacuum bagging	H+A-HL J+A-HL H+A-VB J+A-VB	75% -Epoxy 25%-Fibre

2.2.2. Vacuum bagging method

The stacked fibres and epoxy resin with ratio of 75:25 was vacuum bagged and was cured at room temperature for 24 hrs. Further, it was cured in an air circulated oven.

2.3 Wear Test

Pin-on-disc tribometer (DUCOM India Private Ltd.) was used to perform friction and wear tests. The specimen in test sample holder rubs against the rotating steel counter face and the dead weight was applied through a pulley. The experimental setup is as shown in the figure 1b.



a) b)

Figure 1: a) Worned specimens b) Pin-on-disc wear testing machine

Specimens prepared were as per the ASTM G99 standard. To maintain the initial surface condition and to remove debris, the steel plate was rubbed with abrasive paper and was cleaned by acetone. After each trial sliding speed, load applied and sliding distance parameters were considered to evaluate frictional force and specific wear rate of the specimen. The recorded values of frictional force, coefficient of friction and wear and their plots were obtained from the digital test report.

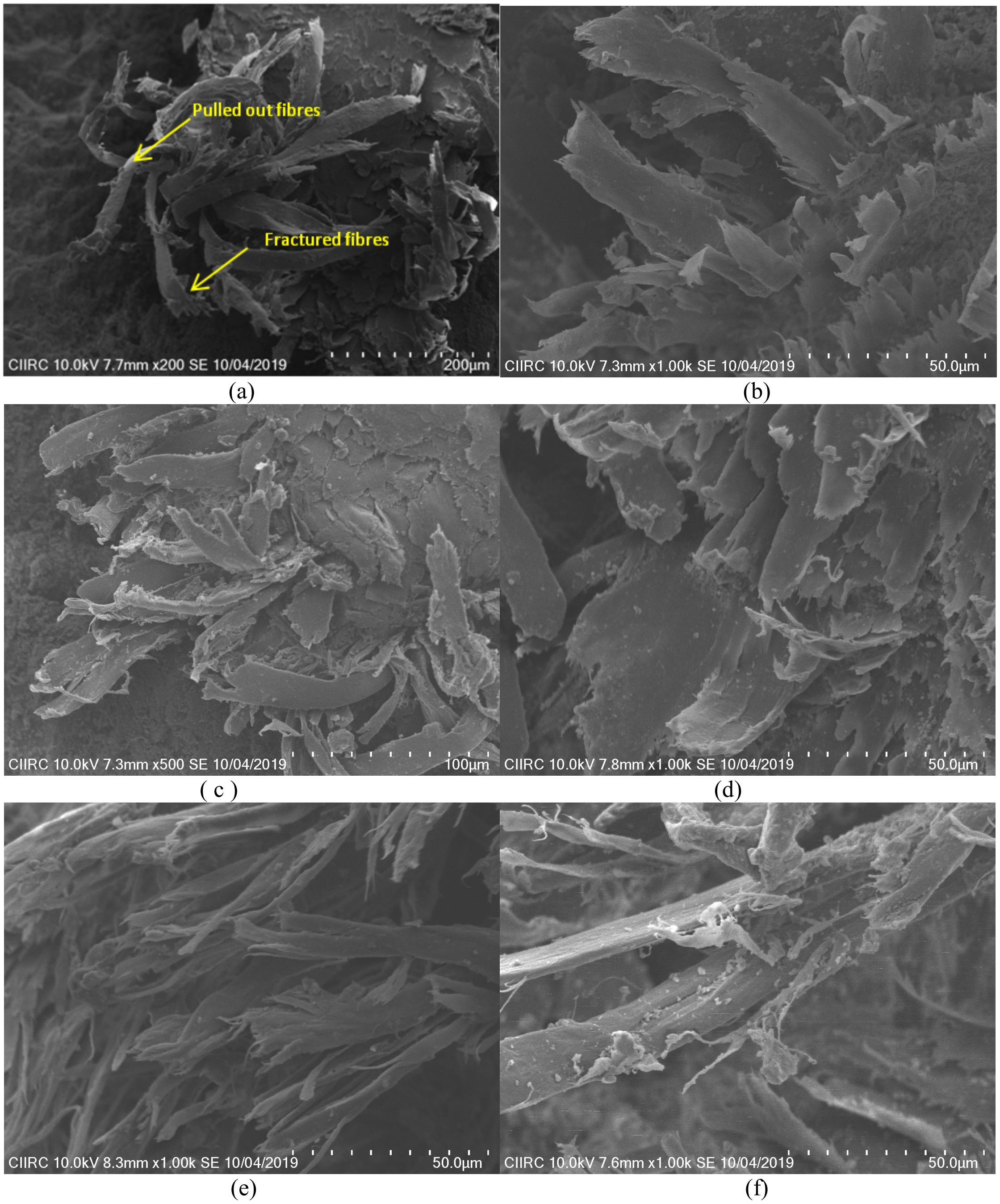
$$\text{Coefficient of friction } (\mu) = \text{Friction force} / \text{Applied load}$$

The mass loss obtained from the test results were used to calculate wear rate using following relation

$$\text{Wear rate} = \text{Mass loss during test} / \text{Sliding distance}$$

III. Results and discussions

3.1 Microstructure studies


Pulled out fibres
Fractured fibres
CIIRC 10.0kV 7.7mm x200 SE 10/04/2019 200µm
(a)
CIIRC 10.0kV 7.3mm x1.00k SE 10/04/2019 50.0µm
(b)
CIIRC 10.0kV 7.3mm x500 SE 10/04/2019 100µm
(c)
CIIRC 10.0kV 7.8mm x1.00k SE 10/04/2019 50.0µm
(d)
CIIRC 10.0kV 8.3mm x1.00k SE 10/04/2019 50.0µm
(e)
CIIRC 10.0kV 7.6mm x1.00k SE 10/04/2019 50.0µm
(f)

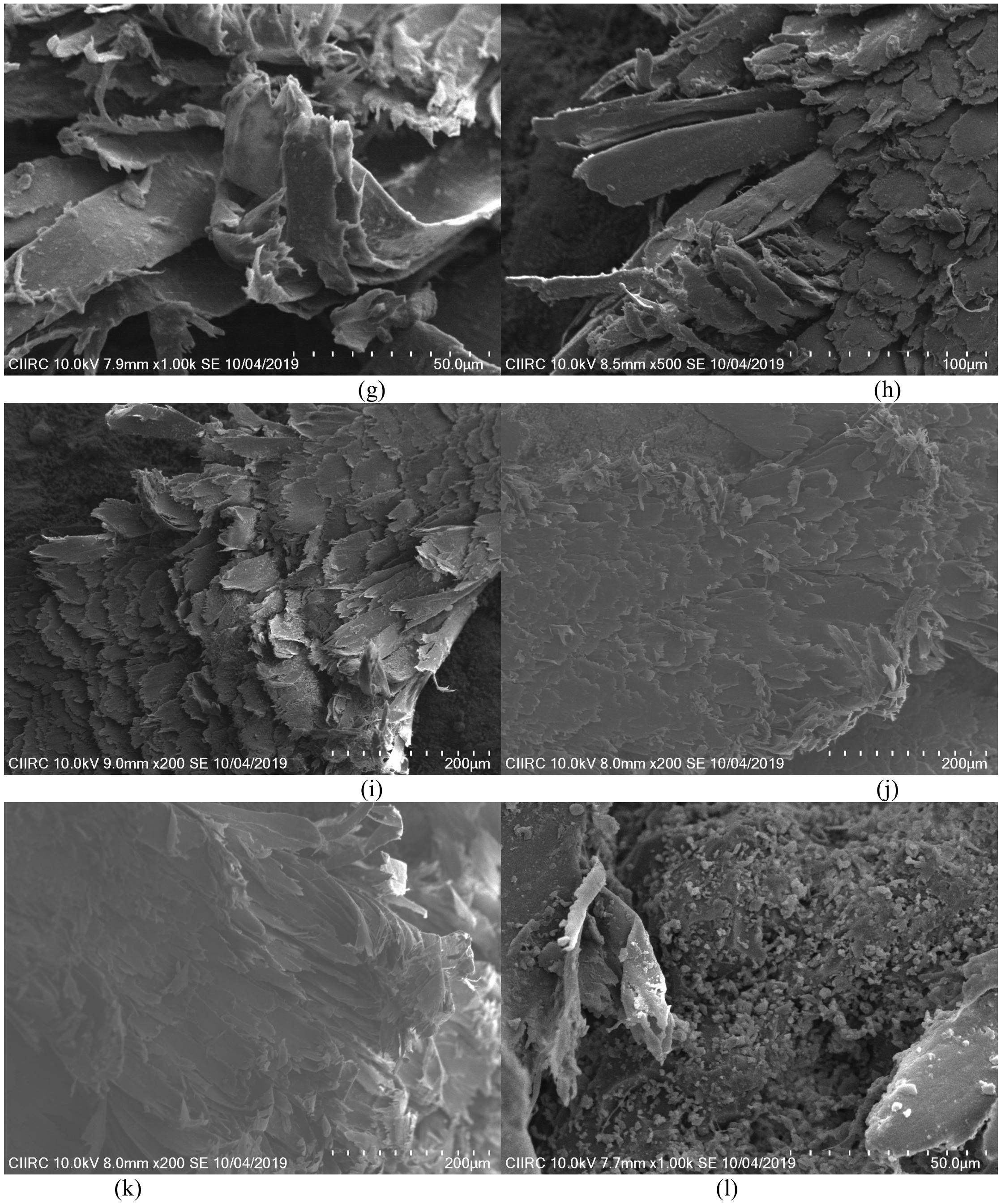


Figure 2 : Micrograph images of (a) H+A-HL at 200 rpm (b) J+A-HL at 200 rpm (c) H+A-VB at 200 rpm (d) J+A-VB at 200 rpm (e) H+A-HL at 300 rpm (f) J+A-HL at 300 rpm (g) H+A-VB at 300 rpm (h) J+A-VB at 300 rpm (i) H+A-HL at 400 rpm (j) J+A-HL at 400 rpm (k) H+A-VB at 400 rpm (l) J+A-VB at 400 rpm

SEM analysis of the worn out composite surfaces were carried out. Figure2 shows the micrograph images of hybrid composites at three different rpm of wear test (200 rpm, 300 rpm and 400 rpm). Figure 2(a) shows the surface of hemp-aramid hybrid composite manufactured by hand layup method at low speed wear test. The micrograph reveals pulled out fibres and fibres are de-bonded from resin and are fractured as they are subjected to stress. As the rpm is increased for the same composite in figure 2(i) the fibres are still bonded to the matrix and are not separated from each other. In comparison to vacuum bagging technique where the same composites are subjected to wear test, figure 2(c) also shows fibres end de-bonded but not deformed. In figure 2(k) at higher rpm, fibres are not separated from matrix and are still bonded together.

Similarly, the fibres are replaced with jute and aramid. In figure 2(b) at low rpm fibres are exposed where as in figure 2(j) less fibres are exposed but still bonded together. In figure 2(l) fibres and matrix are still bonded with small debris.

3.2 Effect of manufacturing technique on wear rate of Hybrid Polymer composite

Table 1: Wear rate of different composition of Hybrid Polymer composite

Test No	Test Sample Composition	Speed , Rpm	Wear track dia, mm	Average COF	Average frictional force , N	Mass loss, mg	Wear rate, mg/km
1	H+A-HL	200	120	0.42	4.2	0.18	0.159
2	J+A-HL	200	120	0.336	3.36	0.30	0.274
3	H+A-VB	200	120	0.382	3.82	0.09	0.079
4	J+A-VB	200	120	0.29	2.9	0.28	0.247
5	H+A-HL	300	80	0.372	3.72	0.30	0.274
6	J+A-HL	300	80	0.486	4.86	0.44	0.389
7	H+A-VB	300	80	0.219	2.19	0.28	0.246
8	J+A-VB	300	80	0.302	3.02	0.39	0.345
9	H+A-HL	400	60	0.617	6.17	0.64	0.570
10	J+A-HL	400	60	0.304	3.04	0.59	0.530
11	H+A-VB	400	60	0.428	4.28	0.63	0.557
12	J+A-VB	400	60	0.4	4.00	0.51	0.450

The results are tabulated and the corresponding graphs are plotted for three different speed. From the micrographs and the graph plotted, the analysis shows that wear rate decreases initially and almost remains same for the entire test period. The graph plotted confirms among the two manufacturing technique, both the composites (H+A-VB and J+A-VB) manufactured by the vacuum bagging technique shows lower wear rate with decreased coefficient of friction. Hence, the vacuum bagging method increases the bonding strength when compared with the conventional hand layup technique.

3.2 Effect of speed on wear rate of Hybrid Polymer composite

The fig 3.1 and fig 3.2 show that irrespective of the manufacturing technique, as the speed increases, the wear rate decreases evidently. This can also be noticed in the micrographs of the test run composites where the fibres are pulled out in the low speed test run composites as against the high speed test run. The fig show lower wear rate.

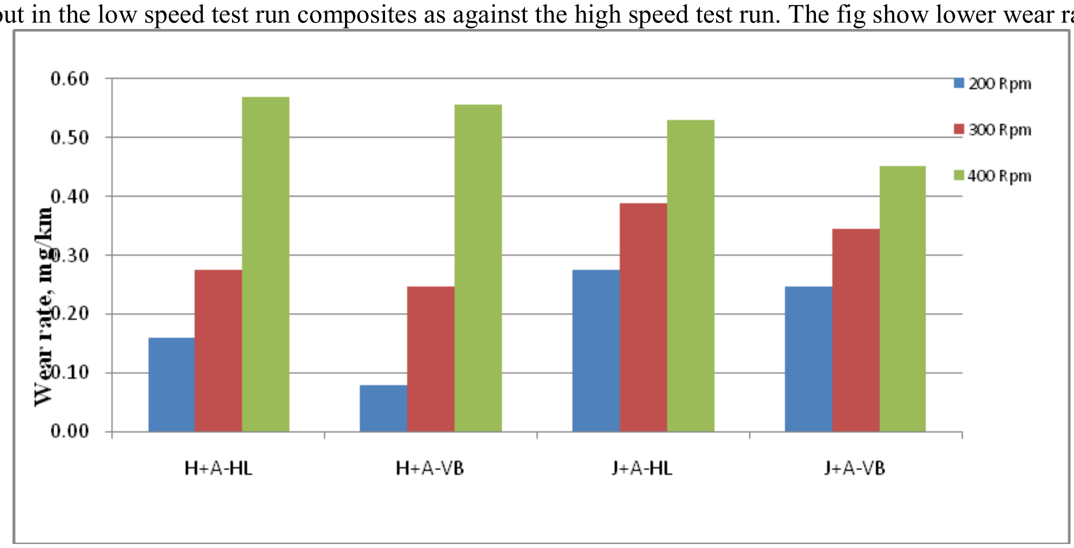


Fig 3.1: Variation of wear rate with different reinforcements and different speeds.

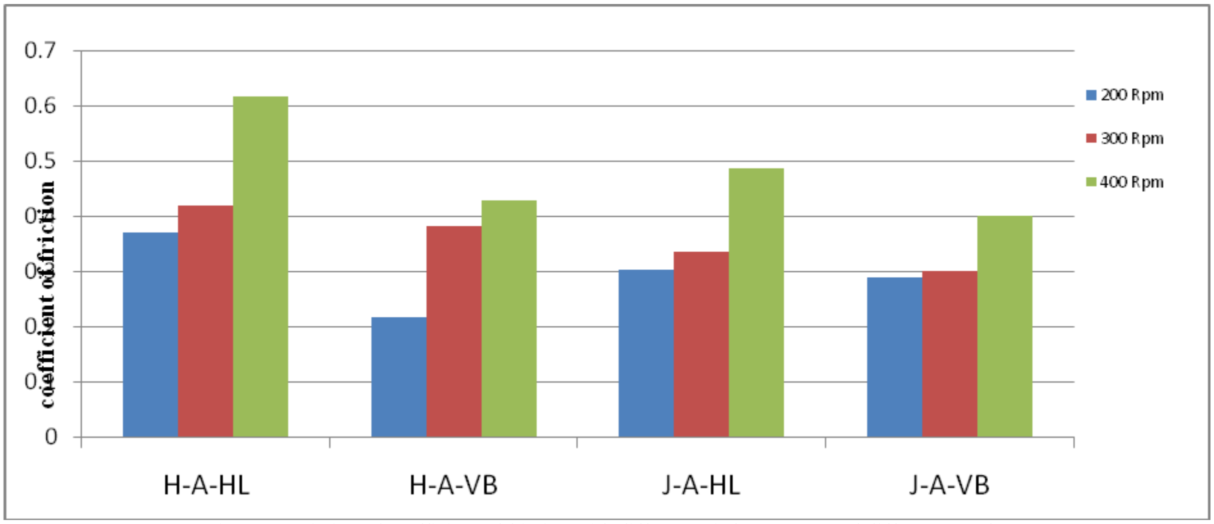


Fig 3.2: Variation of coefficient of friction with different reinforcements and different speeds.

IV.CONCLUSIONS

1. It is clear from experimental work that Vacuum bagging technique shows low wear rate compared to hand layup in both combination that is Hemp-Aramid with Epoxy and Jute-Aramid with Epoxy.
2. From worn out microstructural studies it is clear that Vacuum bagging technique based composites have more bondage between the layers compared to hand lay-up technique.it is observed that fibres are not separated from matrix in worned out surfaces for vacuum bagging technique . Due to this wear resistance is more in vacuum bagging technique compered to hand land layup.
3. The Experimental details shows that as the speed increases, wear rate also increases for both combinations of composites.
4. It is clear from the investigation that the Vacuum bagging technique shows low co-efficient of friction compared to hand layup in both combination that is Hemp-Aramid with Epoxy and Jute-Aramid with Epoxy

REFERENCES

[1] Yadav, P. S., Purohit, R., & Kothari, A. (2019). ScienceDirect Study of Friction and Wear Behaviour of Epoxy / Nano SiO_2 based Polymer Matrix Composites- A Review. *Materials Today: Proceedings*, *18*, 5530–5539. https://doi.org/10.1016/j.matpr.2019.07.666

[2] P. K. Bajpai, I. Singh, and J. Madaan, Proc. Inst. Mech.Eng. PartJ: J. Eng. Tribol., 227, 385 (2013).

[3] C. E. Correa, S. Betancourt, A. Vazquez, and P. Ganan,Tribol Int., 87, 57 (2015).

[4] Muralidhara, B., Babu, S. P. K., & Suresha, B. (2019). Materials Today : Proceedings Utilizing vacuum bagging process to prepare carbon fiber / epoxy composites with improved mechanical properties. *Materials Today: Proceedings*, (xxxx). https://doi.org/10.1016/j.matpr.2019.09.051

[5] Jesthi, D. K., Zanin, A., & Wernke, R. (2018). Enhancement of mechanical and specific wear properties of Enhancement of mechanical and specific wear properties of glass / carbon fiber reinforced polymer hybrid composite Conference hybrid glass / carbon fiber reinforced polymer composite. *Procedia Manufacturing*, *20*, 536–541. https://doi.org/10.1016/j.promfg.2018.02.080

[6] Chaudhary, V., Bajpai, P. K., & Maheshwari, S. (2018). An Investigation on Wear and Dynamic Mechanical behavior of Jute / Hemp / Flax Reinforced Composites and Its Hybrids for Tribological Applications, *19*(2), 403–404. https://doi.org/10.1007/s12221-018-7759-6

[7] Paturkar, A., Mache, A., Deshpande, A., & Kulkarni, A. (2018). ScienceDirect Experimental investigation of dry sliding wear behaviour of jute / epoxy and jute / glass / epoxy hybrids using Taguchi approach. *Materials Today: Proceedings*, *5*(11), 23974–23983. https://doi.org/10.1016/j.matpr.2018.10.190

[8] Swarup, S., Kumar, A., & Kumar, D. (2018). ScienceDirect Evaluation of mechanical and wear performance of glass / carbon fiber reinforced polymer hybrid composite. *Materials Today: Proceedings*, *5*(9), 19854–19861. https://doi.org/10.1016/j.matpr.2018.06.350

[9] Gupta, M. K., & Srivastava, R. K. (2015). Effect of Sisal Fibre Loading on Wear and Friction Properties of Jute Fibre Reinforced Epoxy Composite, (October).

[10] Berhanu, T., Kumar, P., & Singh, I. (2014). Sliding Wear Properties of Jute Fabric Reinforced Polypropylene Composites. *Procedia Engineering*, *97*, 402–411. https://doi.org/10.1016/j.proeng.2014.12.264

[11] Sudeepan, J., Kumar, K., Barman, T. K., & Sahoo, P. (2014). Study of friction and wear properties of ABS / Kaolin polymer composites using grey relational technique. *Procedia Technology*, *14*, 196–203. https://doi.org/10.1016/j.protcy.2014.08.026

[12] Panda, P., Mantry, S., Mohapatra, S., & Singh, S. K. (2014). A study on erosive wear analysis of glass fiber – epoxy – AlN hybrid composites. https://doi.org/10.1177/0021998312469239
[13] Zhong, L. X., Fu, S. Y., Zhou, X. S., & Zhan, H. Y. (2011). Composites : Part A Effect of surface microfibrillation of sisal fibre on the mechanical properties of sisal / aramid fibre hybrid composites. *Composites Part A*, *42*(3), 244–252. https://doi.org/10.1016/j.compositesa.2010.11.010
[14] Theiler, G., & Gradt, T. (2010). Friction and wear of PEEK composites in vacuum environment, *269*, 278–284. https://doi.org/10.1016/j.wear.2010.04.007
[15] Tosun, N. (2002). Effect of load and speed on the wear behaviour of woven glass fabrics and aramid fibre-reinforced composites, *252*, 979–984.
[16] Zhang, H., Zhong, Z., & Feng, L. (1912). Advances in the Performance and Application of Hemp Fiber, 1–5.