ADVERTISEMENT

Log In | Register | Cart
ACS | ACS Publications | C&EN | CAS
ACS Journals | ACS eBooks | C&EN Global Enterprise
Search | Citation | Subject | Advanced Search
Enter search text / DOI | Anywhere | Search
ACS Appl. Mater. Interfaces | All Publications/Website

ACS APPLIED MATERIALS & INTERFACES
ACS Appl. Mater. Interfaces | ACS Appl. Energy Mater. | ACS Appl. Nano Mater.

Research Article

Previous Article | Next Article | Table of Contents

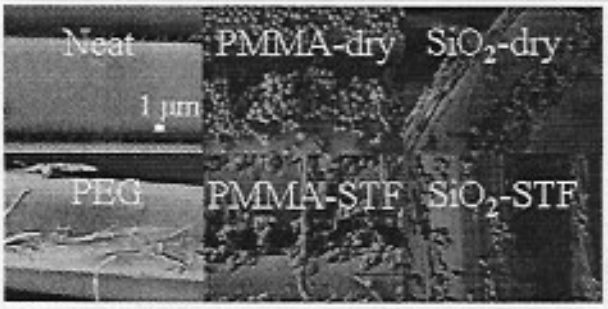
Effect of Particle Hardness on the Penetration Behavior of Fabrics Intercalated with Dry Particles and Concentrated Particle–Fluid Suspensions

Dennis P. Kalman†, Richard L. Merrill‡, Norman J. Wagner† and Eric D. Wetzel*‡
Department of Chemical Engineering and Center for Composite Materials, University of Delaware, Newark, Delaware 19716, and U.S. Army Research Laboratory, Materials Division, Aberdeen Proving Ground, Maryland 21005

ACS Appl. Mater. Interfaces, 2009, 1 (11), pp 2602–2612
DOI: 10.1021/am900516w
Publication Date (Web): November 3, 2009
Copyright © 2009 American Chemical Society

* To whom correspondence should be addressed. E-mail: ewetzel@arl.army.mil. † University of Delaware. ‡ U.S. Army Research Laboratory.

Abstract



The penetration behavior of Kevlar fabric intercalated with dry particles and shear thickening fluids (STF), highly concentrated fluid−particle suspensions, is presented. In particular, the role of particle hardness is explored by comparing fabric treatments containing SiO_2 particles, which are significantly harder than Kevlar, to treatments containing softer poly(methyl methacrylate) (PMMA) particles. The fabric testing includes yarn pull-out, quasi-static spike puncture, and ballistic penetration resistance, performed on single fabric layers. It was found that both dry particle and STF treatments resulted in improvements in fabric properties relative to neat or poly(ethylene glycol) (PEG) treated fabrics. On comparison of treatments with different particle hardness, the SiO_2 materials performed better in all tests than comparable PMMA materials, although the SiO_2 treatments caused yarn failure in pull-out testing, reducing the total pull-out energy. In addition, resistance to yarn pull-out was found to be substantially higher for STF-treated fabrics than for dry particle treated fabrics. However, both dry particle addition and STF treatments exhibited comparable enhancements in puncture and ballistic resistance. These observations suggest that viscous stress transfer, friction, and physical entrainment of hard particles into filaments contribute to the demonstrated improvements in the properties of protective fabrics treated with shear thickening fluids.

Keywords: ballistic; Kevlar; nanoparticles; shear-thickening; spike puncture; yarn pull-out

View: PDF | PDF w/ Links | Full Text HTML

Related Content

Article Options
PDF (3MB) | PDF w/ Links (5MB) | Full Text HTML
Abstract | Supporting Info | Figures | References
Add to Favorites | Download Citation | Email a Colleague | Order Reprints | Rights & Permissions | Citation Alerts
Add to ACS ChemWorx
SciFinder | Sign in
Retrieve Detailed Record of this Article
Retrieve Substances Indexed for this Article
Retrieve All References Cited for this Article
Retrieve All References Citing this Article
Explore by:
Author of this Article | Any Author | Research Topic
Kalman, Dennis P. | Search

Metrics

Article Views: 1,047 Times

Received 4 August 2009
Date accepted 15 October 2009
Published online 3 November 2009
Published in print 25 November 2009

Learn more about these metrics
+ More Article Metrics
CURRENT ISSUE | LATEST NEWS

International Journal of Impact Engineering

Volume 80, June 2015, Pages 143-151

Shear thickening fluid impregnated ballistic fabric composites for shock wave mitigation

Author links open overlay panelA.HarisH.P.LeeT.E.TayV.B.C.Tan

Show more

https://doi.org/10.1016/j.ijimpeng.2015.02.008Get rights and content

Highlights

Twaron fabric systems show improved shock wave protection after STF treatment.

Normalised transmitted pressure decreased from 2.46 to 1.49 after STF treatment.

Normalised rate of pressure rise decreased from 2.3 to 0.76 after STF treatment.

Apparent material density is correlated with peak pressure and pressure rise rate.

Abstract

This study reports on the shock wave protective performance of woven Twaron fabric impregnated with shear thickening fluid (STF). The STF was prepared from a combination of mechanical and ultrasonic mixing of fumed silica nanoparticles dispersed in liquid polyethylene glycol (PEG) polymer. The shear thickening characteristics were determined from rheological tests. Two shock wave parameters governing blast related injuries are used to evaluate the performance of the STF treated fabrics – peak pressure and rate of pressure rise. The results of our shock tube tests demonstrate that the STF treated fabric composites offer superior shock wave protection as compared to untreated (neat) fabric and fabric impregnated with PEG only. After STF treatment, the normalised average peak pressure amplification is significantly reduced from 2.46 to 1.49 while the attenuation in normalised maximum rate of pressure rise is even more pronounced – from 2.3 to 0.76. Apparent material density is found to correlate with the average peak pressure and maximum rate of pressure rise. This implies that the density increases enough to increase the equilibrium sound speed in the fabric, and therefore preclude the formation of shock wave in the fabric. Ballistic tests using steel projectiles were also conducted to check that the STF treated fabrics continued to enhance ballistic protection as reported by other researchers. Overall, the results show that the STF treated fabrics have potential applications not only for ballistic protection but also for shock wave mitigation.

Materials & Design

Volume 89, 5 January 2016, Pages 286-293

Interactive effects of *p*-aramid fabric structure and shear thickening fluid on impact resistance performance of soft armor materials

Author links open overlay panelAnimeshLahaAbhijitMajumdar

Show more

https://doi.org/10.1016/j.matdes.2015.09.077Get rights and content

Highlights

Weave structure and shear thickening fluid influence the impact resistance of armor materials.

Plain weave has the highest impact energy absorption capacity and it improves with higher thread density.

Treatment with shear thickening fluid improves the impact resistance significantly irrespective of weave.

Shear thickening fluid treated plain weave structure with 30 × 30 thread density is the best material for soft armor.

Abstract

Soft body armors are generally made with fabrics woven from high performance yarns. Impact resistance of woven fabrics mostly depends upon fiber type, weave and thread density. Of late, woven fabrics made from high performance yarns are being impregnated with shear thickening fluids (STFs) to enhance their impact resistance. In this research, five different weave structures were prepared with varying thread densities of *p*-aramid (Technora) yarns, followed by treatment with 60% w/w STF to develop soft armor materials. Untreated and STF treated Technora fabrics were evaluated for energy absorption using dynamic impact resistance tester. In untreated condition, plain woven fabrics showed the highest impact resistance, followed by 3/1 twill, 2/2 twill, 5 end satin and 2/2 matt. STF treatment improved the impact resistance performance in all the weave structures and thread densities except for the plain weave with the highest thread density. The ascending order of weaves in terms of enhancement in impact energy absorption after STF treatment was exactly opposite to the ascending order of weaves in terms of impact energy absorption before STF treatment.

Graphical abstract

Progress in Polymer Science

Volume 75, December 2017, Pages 48-72

Review

Shear thickening fluids in protective applications: A review

Author links open overlay panelSelimGürgen[a,b]Melih CemalKuşhan[c]WeihuaLi[a]

Show more

https://doi.org/10.1016/j.progpolymsci.2017.07.003Get rights and content

Abstract

A thorough and critical review on Shear Thickening Fluids (STFs) is presented based on a literature survey. The rheological properties of STFs are discussed considering many factors affecting shear thickening behavior and the use of STFs in protective systems is reviewed. The main focus of this review is multi-phase STFs, relatively new to the literature (in the last five years). Multi-phase STFs include a second phase in suspensions and the influences of this additional phase on rheological behavior and protective applications are discussed extensively. Based on this extended review, STF do benefit protective applications, but the major contribution is not driven by the shear thickening behavior. Rather, STFs are responsible for the increase in friction along fabrics and enhanced fiber/yarn coupling in fabric based protective systems. As a result, of these effects, the load transfer is spread over a wider area and penetration depth is lowered in an impacted structure.

Composites Part B: Engineering

Volume 97, 15 July 2016, Pages 162-175

Shear behavior of a shear thickening fluid-impregnated aramid fabrics at high shear rate

Author links open overlay panelWonjinNa[a]HyunchulAhn[a]SungjinHan[a]PhilipHarrison[b]Jong KyooPark[c]EuigyungJeong[c]Woong-RyeolYu[a]

Show more

https://doi.org/10.1016/j.compositesb.2016.05.017Get rights and content

Abstract

Shear-thickening fluid-impregnated aramid (STF-im-AR) fabrics have been manufactured for advanced soft body armor applications for which they provide improved ballistic and stab resistances. It is not yet clear whether or not such improvements can be attributed solely to the STF. In this study, the rate-dependent behavior of an STF-im-AR fabric was investigated at the fabric level, using uniaxial tensile, bias-extension, and picture-frame tests. Rate-dependent behavior of the STF-im-AR fabric was observed during uniaxial tensile testing; however, the effect of the STF treatment was slight and consistent with only the inherent effect of the polymeric nature of its constituent fibers. The shear rigidity of the STF-im-AR fabric increased, due to the presence of the STF and the sensitivity of the fabric's shear stiffness to changes in the shear strain rate also increased slightly. This rate-sensitive shear stiffness of STF-im-AR fabrics may contribute to improved ballistic and stab resistances.

STF SG - Standard

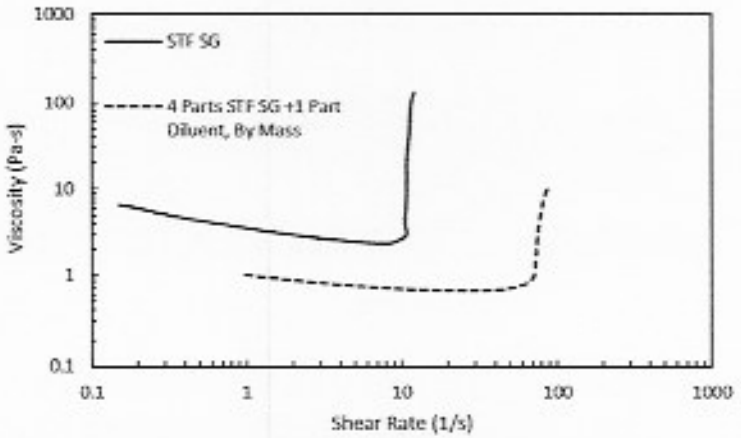
Concentrated suspension of inorganic particles in a glycol medium

STF SG is a hydrophilic shear thickening fluid formulation that is optimal for exploring the potential benefits of STFs in multiple applications. STF-SG has flow properties that typically offer good all-around performance in a variety of applications, including enhancement of textiles for improved puncture resistance, impact protection, motion-control, and educational demonstrations.

Benefits

- Exhibits strong shear thickening at rates relevant to human motion and protective applications
- Enhances puncture-resistance of many types of protective textiles
- Capable of absorbing significant impact energy
- Non-toxic, non-volatile formulation
- Hydrophilic chemistry is compatible with many textiles
- Easy to mix and dilute with alcohols for textile treatment

An optional diluent is available which allows the user to easily experiment with shear thickening fluids having different critical rates. The figure below illustrates how the diluent allows for adjustment of the strength of shear thickening and the critical shear rate to facilitate optimization in the desired application.



Example flow curves for STF SG measured at 25°C illustrating the ability to control the critical rate at which shear thickening occurs