Advances in Automobile Engineering

Zhu and Qiu, Adv Automob Eng 2017, 6:4
DOI: 10.4172/2167-7670.1000170

Short Communication Open Access

Possible Application of Tough Hydrogel in Machinery

Longxiang Zhu and Jianhui Qiu*

Department of Machine Intelligence and Systems Engineering Faculty of Systems Engineering, Akita Prefectural University, Japan

Abstract

Like a solid, hydrogels do not flow. Like a liquid, small molecules diffuse through a hydrogel. Hydrogels are currently viewed as water-insoluble soft and wet materials, and they are usually composed of three-dimensional polymer network structure and a large amount of water (50 ~ 99%). It has potential applications in many fields, such as, drug delivery system, superabsorbent, biosensor, tissue engineering, wound dressing, and battery.

Keywords: Hydrogels; Tissue engineering; Mechanical properties; Industrial products

Introduction

Like a solid, hydrogels do not flow. Like a liquid, small molecules diffuse through a hydrogel. Hydrogels are currently viewed as water-insoluble soft and wet materials, and they are usually composed of three-dimensional polymer network structure and a large amount of water (50 ~ 99%) [1]. It has potential applications in many fields, such as, drug delivery system, superabsorbent, biosensor, tissue engineering, wound dressing, and battery.

However, the conventional hydrogels exhibit poor mechanical properties, such as, low fracture energy of 1 ~ 10 J/m^2 and low elastic modulus of ~ 10 kPa. The drawbacks greatly limit the use of hydrogels in the fields of materials. In recent years, the designed hydrogels have overcame this shortcoming depending on the energy dissipation mechanism [2]. For example, Gong et al. have explained the reinforce mechanism of double-network hydrogels in detail [3]. The double network hydrogels are tough because the internal fracture of the brittle network dissipates substantial amounts of energy under large deformation, while the elasticity of the second network allows it to return to its original configuration after deformation. The fracture energy of double network hydrogel can increase from 1 ~ 10 J/m^2 to 1000 J/m^2 compared to the conventional hydrogel. To date, some of the reported hydrogels not only possess mechanical strength but also show similar properties of rubber, including, high resilience and rapid recovery. It makes the hydrogel possible as impact and vibration absorbing materials in the field of industrial products.

Discussion

In 2008, Osawa reported a hydrogel as a vibration absorber for automobile [4]. A viscoelastic hydrogel is placed between the weight and the bracket base as a vibration absorbing material, as shown in Figure 1. The hydrogel can suppress resonance caused by engine idling vibration. However, limited by the strength of the hydrogel at that time, this design has not been widely used.

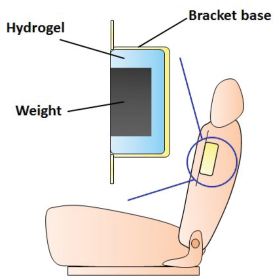

Figure 1: Application of hydrogel in car cushion.

Recently, our group report a method of preparing a rubbery carboxymethyl cellulose/polyacrylic acid (CMC/PAA) hydrogel through a facile, one-pot, visible-light-triggered polymerization [5]. The tensile strength, fracture elongation, and modulus of the hydrogel are 400-850 kPa, 350-700%, and 65-180 kPa, respectively. The hydrogel has a typical Mullins effect similar to rubber. The hydrogel can endure large deformation and has excellent fast recovery performance (the response time within 10 ms, as shown in Figure 2.

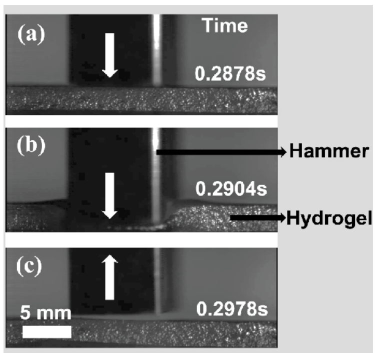

Figure 2: Recovery time of hydrogel during an impact experiment.

As a kind of engineering material, the resilience and anti-fatigue properties of the hydrogel are also necessary. We have successfully prepared a modified CMC/PAA hydrogel by adding molecule cross-linker (*N, N'*-methylene bis(acrylamide), MBA) [6]. The hydrogel exhibited remarkable resilience (over 93% and 95% for successive and intermittent cyclic tests) and anti-fatigue properties (residual strain less than 3%). In addition, Cui et al. have reported a highly resilient synthetic hydrogel by using the efficient thiol-norbornene chemistry to cross-link hydrophilic poly(ethylene glycol) (PEG) and hydrophobic

***Corresponding author:** Jianhui Qiu, Department of Machine Intelligence and Systems Engineering Faculty of Systems Engineering, Akita Prefectural University, Japan, Tel: +81 18-872-1500; E-mail: qiu@akita-pu.ac.jp

Received September 28, 2017; **Accepted** October 06, 2017; **Published** October 11, 2017

Citation: Zhu L, Qiu J (2017) Possible Application of Tough Hydrogel in Machinery. Adv Automob Eng 6: 170. doi: 10.4172/2167-7670.1000170

Citation: Zhu L, Qiu J (2017) Possible Application of Tough Hydrogel in Machinery. Adv Automob Eng 6: 170. doi: 10.4172/2167-7670.1000170

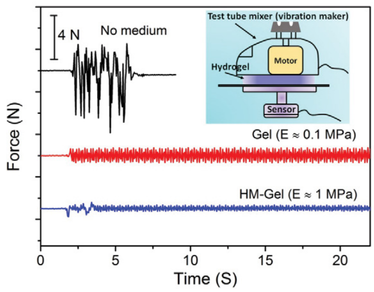

Figure 3: Comparison of vibration absorption effect obtained with different vibration damper in free mode.

polydimethylsiloxane (PDMS) polymer chains [7]. The mechanical storage efficiency (resilience) can reach as high as 97% at the strain of 300%. The hydrogels have potential applications in soft machines and biomaterials.

Although the strength of these hydrogels can reach several hundred kPa to several MPa, these hydrogels are generally shown low elastic modulus (usually less than 0.1 MPa) as compared to conventional rubbers (more than 1 MPa) [8]. Thus, even under small external force, these hydrogels will have a large deformation, which limits the load of these hydrogels. To obtain a hydrogel with high modulus, we leveraged the hydrogen bonds in the hydrogel to induce a CMC crystallization to alter the network structure within the hydrogel via the evaporation-swelling method. The obtained optimal high modulus hydrogel (HM-Gel) possessed excellent mechanical properties with tensile strength and elastic modulus of 1.55 MPa and 1.02 MPa, respectively [9]. The HM-Gel exhibited stable mechanical properties in both the cyclic tensile and compression tests. The preliminary application experiment shows that the hydrogel has a significant vibration absorption effect. Moreover, high-modulus hydrogel has a better vibration absorption effect than the low-modulus hydrogel in the experiment (Figure 3). The results indicated that hydrogel as a new type of vibration absorption material can be used in industrial manufacturing.

Furthermore, hydrogels, as functional materials, also have some potential applications in the field of temperature control, self-degradation, and fire-proof material. For example, we can add phase change energy storage [10] reagent in hydrogel during the hydrogel preparation process to prepare the automatic temperature control material. This material consist of water (high specific heat capacity) and phase change energy storage component, which can reduce the consumption of energy when using air conditioning to control the temperature in the car.

Conclusion

In conclusion, with the deep study of hydrogel properties, we believe that hydrogel is not only as an excellent biological material, but also play an important role in the fields of automobile, aerospace etc.

References

1. Chen Q, Chen H, Zhu L, Zheng J (2015) Fundamentals of double network hydrogels. J Mater Chem B 3: 3654-3676.
2. Zhao X (2014) Multi-scale multi-mechanism design of tough hydrogels: Building dissipation into stretchy networks. Soft Matter 10: 672-687.
3. Gong JP (2014) Materials science. Materials both tough and soft. Science 344: 161-162.
4. Osawa K (2008) Vibration isolating device, vehicular seat, and production method of vibration isolating device. Japanese patent JP, 2008-29673, A.
5. Zhu L, Qiu J, Sakai E, Zang L, Yu Y, et al. (2017) Design of a rubbery carboxymethyl cellulose/polyacrylic acid hydrogel via visible-light-triggered polymerization. Macromol. Mater. Eng 302: 1600509.
6. Zhu L, Qiu J, Sakai E, Ito K (2017) Rapid recovery double cross-linking hydrogel with stable mechanical properties and high resilience triggered by visible light. ACS Appl Mater Interfaces 9: 13593-13601.
7. Cui J, Lackey MA, Madkour AE, Saffer EM, Griffin DM, et al. (2012) Synthetically simple, highly resilient hydrogels. Biomacromolecules 13: 584-588.
8. Peak CW, Wilker JJ, Schmidt G (2013) A review on tough and sticky hydrogels. Colloid Polym Sci 291: 2031-2047.
9. Zhu L, Qiu J, Sakai E (2017) A high modulus hydrogel obtained from hydrogen bond reconstruction and its application in vibration damper. RSC Adv 7: 43755-43763.
10. Pereira da Cunha J, Eames P (2016) Thermal energy storage for low and medium temperature applications using phase change materials – A review. Appl Energ 177: 227-238.