ORIGINAL PAPERS

DOI: 10.17073/2500-0632-2019-2-132-143

Selection of Material for Facing Drive Drum of Belt Conveyor

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Abstract: It is known that conveyor operates in chemically aggressive and abrasive environments; for this reason the drive drum of belt conveyor wears out rather rapidly. It is noted that the lining of the conveyor drum increases coefficient of friction between the conveyor drum and the conveyor belt, reduces the belt wear rate, and also protects against corrosion and abrasive wear. The plot of the PU-60 polyurethane wear rate as function of load when rolling on steel is presented. It is noted that increasing the load increases the strength of adhesive junction between steel and polyurethane rollers; friction wear causes fatigue failure of surface layers of the materials. Besides, the plot of the PU-80 polyurethane wear rate as function of load when rolling on steel is presented. The plot of the polyurethanes wear rate as function of hardness of polyurethane is presented, which shows that the lowest wear rate is demonstrated by the hardest polyurethane, PU-80. The bar chart of static friction coefficient for PU-60 and PU-80 polyurethanes demonstrates that the optimal material for lining the drive drum of a conveyor belt is PU-80. The plot of the rubber wear rate as function of load at a speed of 1 m/s is presented. The plot shows that the wear rate increases with increasing the load. This is due to the effect of two factors: growing contact deformations of the surface layer of the rubber and increasing the contact area of mating parts. It is noted that IRP-1347 rubber is less susceptible to wear than "REMAGRIP" rubber. This allows using IRP-1347 rubber in aggressive environments. The bar chart of static friction coefficient for the rubber presented in the paper shows that the investigated IRP-1347 and REMAGRIP rubber grades have the required value of static friction coefficient for use as lining material for the drive drum. The plot of the wear rate as function of the rubber hardness and as function of the polyurethane hardness is presented. In practice, it is proved that the best material for lining the drive drum is PU-80.

Keywords: polyurethane, rubber, lining, wear resistance, static friction coefficient, belt conveyor, linear wear rate, drive drum, strength, elastomer.

For citation: Hrydziushka D. V., Bryzhevich A. V., Piskun E. V. Selection of material for facing drive drum of belt conveyor. *Mining Science and Technology*. 2019;4(2):132-143 (In Russ.). DOI: 10.17073/2500-0632-2019-2-132-143.

Выбор материала для облицовки приводного барабана ленточного конвейера

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Аннотация: Известно, что конвейер работает в химически активной и абразивной средах, по этой причине приводной барабан ленточного конвейера быстро изнашивается. Отмечено, что футеровка конвейерного барабана повышает коэффициент трения между конвейерным барабаном и транспортерной лентой, снижает скорость изнашивания ленты, а также защищает от коррозии и абразивного износа. Представлен график зависимости интенсивности изнашивания полиуретанов ПУ-60 от нагрузки при качении по стали. Показано, что с увеличением нагрузки увеличивается прочность адгезионных соединений между стальным и полиуретановым роликами, при трении материалы повреждаются вследствие усталостного разрушения поверхностных слоев. Также представлен график зависимости интенсивности изнашивания полиуретанов ПУ-80 от нагрузки при качении по стали. Представлена диаграмма зависимости интенсивности изнашивания от твердости полиуретана, на которой видно, что самая маленькая интенсивность изнашивания у самого твердого полиуретана ПУ-80. Проиллюстрирована гистограмма коэффициента трения покоя полиуретанов ПУ-60 и ПУ-80, из которой можно сделать вывод, что оптимальный материал для облицовки приводного барабана ленточного конвейера – это ПУ-80. Представлен график зависимости интенсивности изнашивания резины от нагрузки при скорости 1 м/с. Из графика видно, что интенсивность изнашивания возрастает с повышением нагрузки. Это обусловлено влиянием двух факторов: увеличением контактных деформаций поверхностного слоя резины и увеличением площади контакта сопрягаемых деталей. Отмечено, что резина ИРП-1347 в меньшей степени поддается изнашиванию по сравнению с резиной «REMAGRIP», что позволяет ей работать в агрессивных средах. Гистограмма коэффициента трения покоя для резины, представленная в работе, показывает, что исследуемые резины марок ИРП-1347 и «REMAGRIP» обладают необходимым значением коэффициента трения покоя для использования их в качестве футеровочного материала для приводного барабана. Представлена диаграмма зависимости интенсивности изнашивания от твердости резины и полиуретана. На практике доказано, что наилучшим материалом для облицовки приводного барабана является ПУ-80.

Ключевые слова: полиуретан, резина, облицовка, износостойкость, коэффициент трения покоя, ленточный конвейер, линейная интенсивность изнашивания, приводной барабан, прочность, резина, эластомер.

Для цитирования: Гридюшко Д. В., Брижевич А. В., Пискун Е. В**.** Выбор материала для облицовки приводного барабана ленточного конвейера. *Горные науки и технологии.* 2019;4(2):132-143. DOI: 10.17073/2500-0632-2019-2-132-143.

Introduction

Due to the fact that a conveyor operates in chemically aggressive and abrasive environments the drive drum of a belt conveyor wears out quickly [1]. In order to reduce the wear, the drum lining is required.

There are several types of lining material for drive drum. The selected material should have the following properties:

–high strength and hardness;

–resistance to chemical attack;

–increase the life of the conveyor belt;

–increase friction coefficient between the conveyor drum and the conveyor belt;

–protect against corrosion and abrasion.

Thus, in the course of the study, it is necessary to study the tribotechnical properties of the material proposed for lining the drive drum and determine the material that meets the requirements and has the necessary properties [2].

1. Lining of a conveyor belt drive drum. Drive drums are manufactured by welding with a shell of sheet steel or by iron casting. Regarding the drum shape, the drums are made with a cylindrical or convex (barrel-shaped) surface, smooth or with notches. The drive drum traction properties are improved by increasing the tension of the belt or the angle of the drive drum clasping by the belt, using highly friction lining with longitudinal or chevron ribs (which contributes to self-cleaning) [3].

Lining of a conveyor drum increases friction coefficient between the conveyor drum and the conveyor belt, reduces the belt wear rate, and also protects against corrosion and abrasion.

Lining is installed on the conveyor drum using special adhesives. The lining plates significantly reduce the belt switch and slipping, as well as the ingress of cargo onto the drum surface. This all significantly improves conveyor operation and increases the operation technical and economic indicators.

The ribbed surface of the drive drum provides an increase in coefficient of adhesion of the belt to the drum and the drive traction factor, while reducing the required belt tension [4], increasing service life of the belt and its abutting joints.

The main material used for a drive drum lining is rubber.

A positive property of rubber is its very high elasticity. Rubber is amenable to large deformations, which are almost completely reversible [5]. In addition, rubber is characterized by high tensile and abrasion resistance, gas and water impermeability, chemical resistance, good electrical insulation properties, low density, low compressibility, and low thermal conductivity.

Rubber, as a structural material, in a number of its properties significantly differs from metals and other materials. Distinctive features of rubber are: the ability to withstand significant deformations without fracture under the influence of an external load; small values of shear modulus, modulus of tension, compression modulus; strong influence of the duration of the applied load and the temperature factor on the stress – strain relationship; almost constant volume during deformation; almost complete reversibility of deformation; significant mechanical losses in the process of cyclic deformation.

However, rubber has low abrasion resistance, low operation temperature range, low modulus of elasticity, and low hardness in relation to other materials [6].

Polyurethanes are the most versatile materials available in practical use.

Products made of polyurethane are up to 50 times more wearproof than rubber, plastics, in some applications, nonferrous and ferrous metals. This durability often means that polyurethane parts require less material amount for manufacture and less maintenance, resulting in significant cost savings.

Polyurethane is one of the most rigid (Shore 30–95) and the most abrasion-resistant elastomers, which are not subject to fracture under loads [7]. It has high tensile strength and resistance to incision advancement, resistance to chopping shocks. Products made of polyurethane retain their shape and mechanical properties after cyclic loads.

Products made of polyurethane well withstand multiple bends without breaking.

The product operation temperature range is from −50 to +80 °C, for a short time up to +100 °C. Polyurethane remains flexible at very low temperatures and has good resistance to thermal shock.

Polyurethane has high allowable shear load, good adhesion to most materials, good chemical resistance to oils, petroleum, organic solvents.

The use of polyurethane allows reducing the product weight by up to 50 %, reducing the level of vibration and system noise of operating mechanisms in comparison with metals [8].

2. Polyurethane wear test._With the aim of determining whether polyurethane can work as a lining material for a conveyor belt drive drum, tests were conducted to determine its mechanical and frictional properties.

The essence of the testing is to determine friction coefficient of the material under study against a counterbody made of steel, as well as wear under different loading conditions and speed modes.

For testing, a SMT-1 friction machine was used [9].

Fig.1 shows the test arrangement.

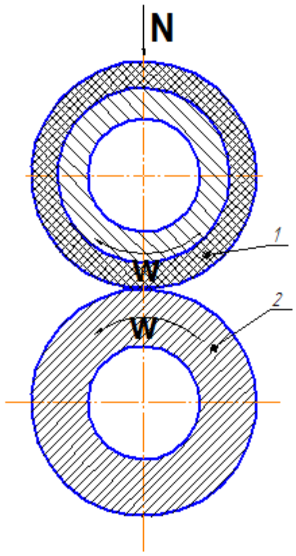

Fig. 1. Arrangement of the tribological technical tests:
1 – polyurethane roller; *2* – Steel 45 roller

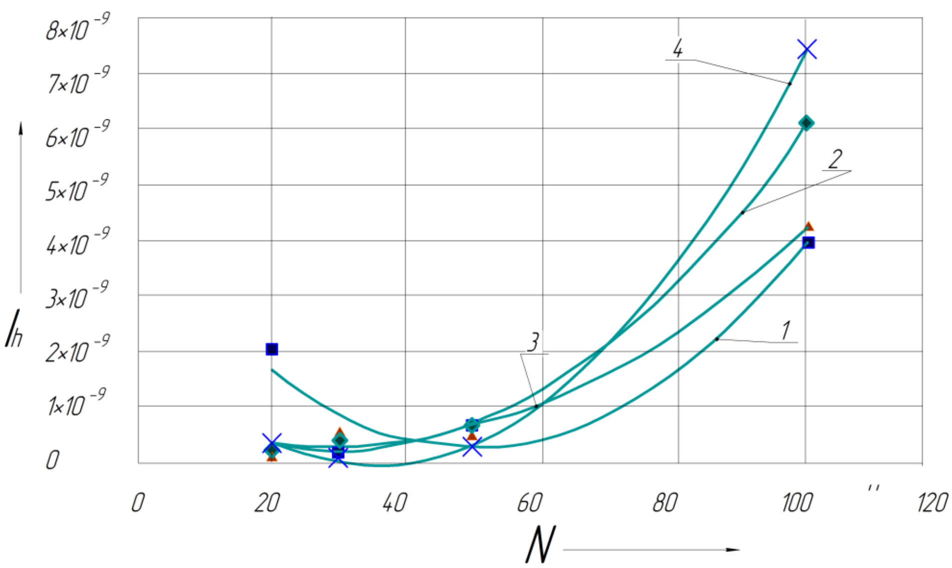

Fig. 2. The plot of PU-60 polyurethane wear rate as function of load when rolling on steel:
1 – 1.25 m/s; *2* – 0.4 m/s; *3* – 0.7 m/s; *4* – 1 m/s

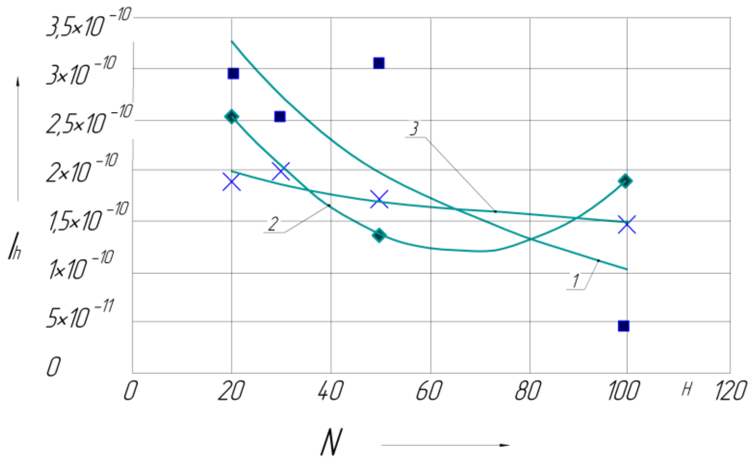

Fig. 3. The plot of PU-80 polyurethane wear rate as function of load when rolling on steel:
1 – 0.25m/s; *2* – 0.4 m/s; *3* – 1 m/s

The testing was performed on samples of PU-60 and PU-80 polyurethane of sizes: D_{inner} = 16 mm; D_{outer} = 40 mm; h = 10 mm. The testing device was a steel roller covered with the testing material.

As a counterbody, a roller made of Steel 45 40 mm in diameter was used.

The tests were carried out at speeds of 0.25 m/s, 0.4 m/s, 0.7 m/s, 1 m/s and loads of 20N, 30N, 50N, 100N for each speed.

After testing, the mass difference of the samples before and after the tests was calculated.

The linear wear rate was determined using formula

$$I_h = \frac{\Delta m}{\rho A S}, \qquad (1)$$

where Δm – mass difference before and after the test, kg;

ρ – density of the test material (1715.74 кг/м^3);

A – friction surface area, m^2;

S – slip path length, m.

3. The influence of loading conditions on the friction and wear of polyurethane.

It can be seen from the graph (Fig. 2) that with increasing the load, the strength of adhesive joints between the steel and polyurethane rollers increases. During friction, materials are damaged due to fatigue failure of surface layers [10]. The destruction occurs by separation, which is due to the gradual destruction of the macromolecule chains under the action of non-critical loads.

Due to the fact that the speed increases, the temperature at the contact spots increases too that leads to increasing the strength of the formed adhesion joints. This explains the higher wear rate at higher speed.

It is seen from the graph (Fig. 3) that on curves 1 and 3, the wear rate decreases. This is due to the fact that, as the load increase, a shift in the inner layers of polyurethane occurs. Internal elastic deformations arise [11], which do not reach the surface that leads to gradual decrease in the wear rate.

Curve 1 (Fig. 3) decreases at a large angle due to the fact that the temperature effect affects to a lesser extent.

On curve 2 (Fig. 3), the dependence of the wear rate on the load is presented by a curve with a minimum. The wear rate decrease, same to curves 1 and 3, is due to the displacement of the inner layers. Increasing wear rate is connected with increasing temperature in the contact zone.

To select polyurethane suitable for drive drum lining, tribotechnical characteristics of the polyurethanes under study should be compared.

It is seen from the graph (Fig. 4) that the lowest wear rate is demonstrated by the hardest PU-80 polyurethane. This is due to the fact that in solid polyurethane has stronger molecular bonds that does not allow breaking at high speeds and loads.

4. Determination of static friction coefficient of polyurethane. Operation of a belt conveyor is based on the transfer of traction force by friction. The traction element of belt conveyors is a belt, which is also a load-carrying surface. Throughout the whole length the belt is supported by stationary rollers. Traction due to the adhesion of the belt with the drum is transmitted to the belt by a drive drum, rotation of which provided by an electric motor through a gearbox [12, 13]. The tensioning device provides the belt tension, which is extremely important for adhesion of the belt to the drum, to prevent slipping of the belt on the drive drums and to limit the sag between the roller bearings.

The movement of the belt on the drive drum surface should occur at optimum static friction coefficient value. This condition is required to minimize the conveyor belt wear. To determine the optimal value of static friction coefficient, tests were carried out, results of which are given in Table 1 [14].

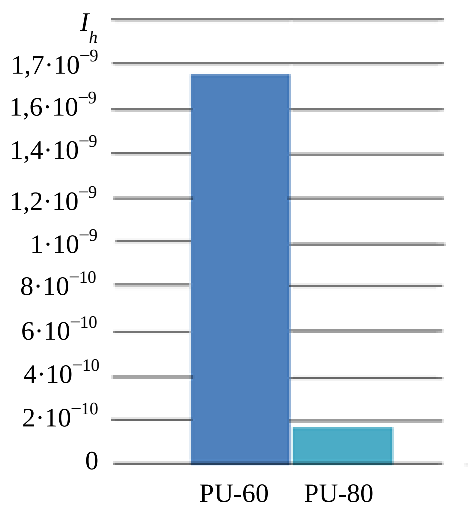

Fig. 4. The plot of wear rate as function of the polyurethane hardness

Table 1

Data of tests for measuring static friction coefficient

Polyurethane grade	Static friction coefficient
PU-60	1.04
PU-80	0.67

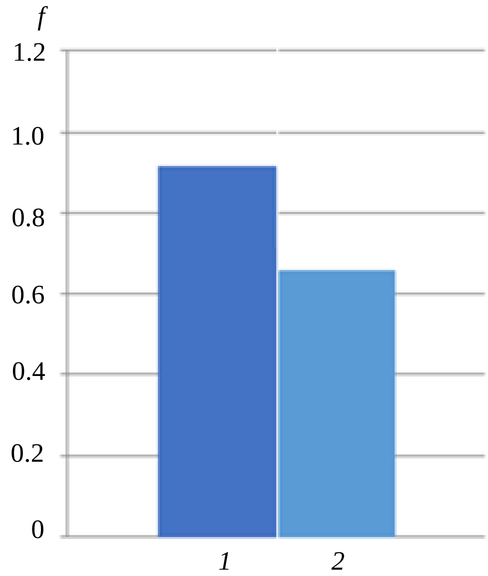

Fig. 5. The bar chart of static friction coefficient for the polyurethane grades:
1 – PU-60; 2 – PU-80

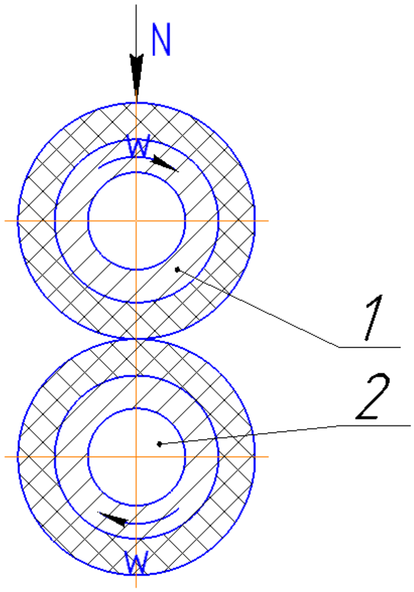

Fig. 6. Arrangement of the tribological technical tests:
1 – rubber roller; *2* – conveyor belt roller

Table 2

Rubber performance indicators

Rubber compound grade	Performance indicators	
	Operating temperature range, °C	Shore hardness, A
IRP-1347	from −50 to 80	47…57
REMAGRIP	from −30 to 80	63 ± 5

The histogram of the polyurethane static friction coefficient (Fig. 5) shows that the studied polyurethanes have the required value of static friction coefficient for the use as a lining material for a drive drum. Static friction coefficient value of PU-80 [15] is sufficient to use this material in the drive drum lining.

Based on this we can conclude that the optimal material for the conveyor belt drive drum lining is PU-80. This polyurethane is durable. It demonstrated high hardness and wear resistance.

5. Rubber wear testing. The testing was performed on samples of the testing material of sizes: D_{inner} = 16 mm; D_{outer} = 40 mm; h = 10 mm, representing a roller (Fig. 6).

As the testing samples, we used rubber grades presented in table 2 [8, 16].

A roller 40 mm in diameter from the conveyor belt was used as counterbody.

The tests were carried out 3 times at a speed of 1 m/s; the applied loads amounted to 20N; 30H; 50H. After the testing, the arithmetic average of all the wear rate values was calculated and comparative charts were built.

6. The influence of loading conditions on friction and wear of rubber

It is seen from the graph (Fig. 7) that the wear rate increases with increasing the load. This is due to the influence of two factors [17]:

–contact deformations of the surface rubber layer increase and, as a result, the probability of fatigue failure of this layer increases.

–the contact area of the mating parts increases and a larger number of adhesive bonds is formed, accompanied by an increase in the friction coefficient. As a result, adhesive wear of rubber proceeds more intensively.

As the speed increases, the temperature in the contact also increases that leads to the growth of the contribution of both wear types.

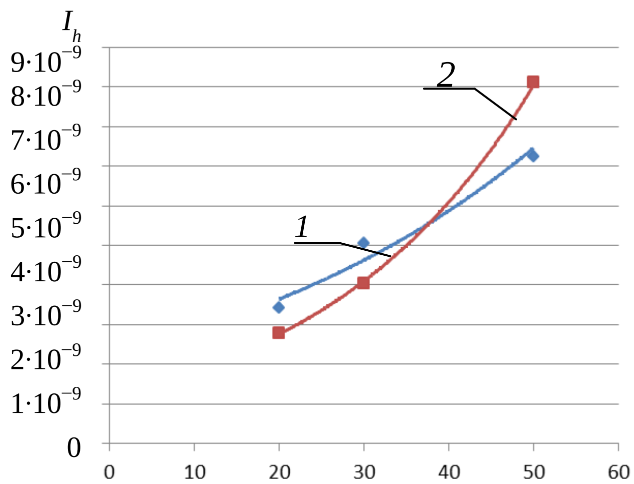

Fig. 7. The plot of the rubber grade wear rate as function of load at a speed of 1 m/s:
1 – IRP-1347 rubber; *2* – "REMAGRIP" rubber

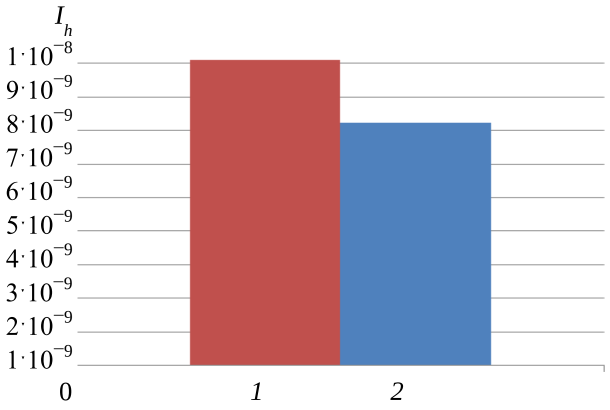

Fig. 8. The plot of wear rate as function of the rubber grade hardness:
1 – REMAGRIP rubber; *2* – IRP-1347 rubber

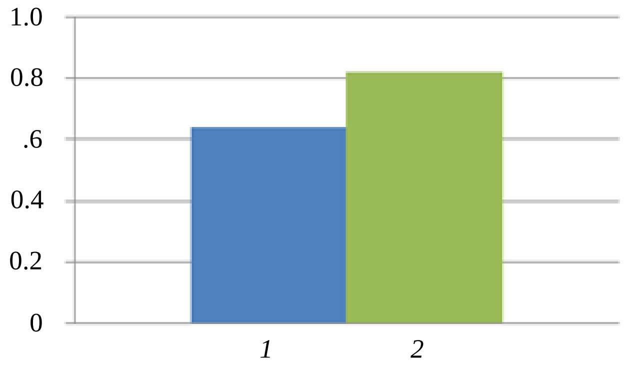

Fig. 9. The bar chart of static friction coefficient for the rubber grades:
1 – IRP-1347; *2* – "REMAGRIP"

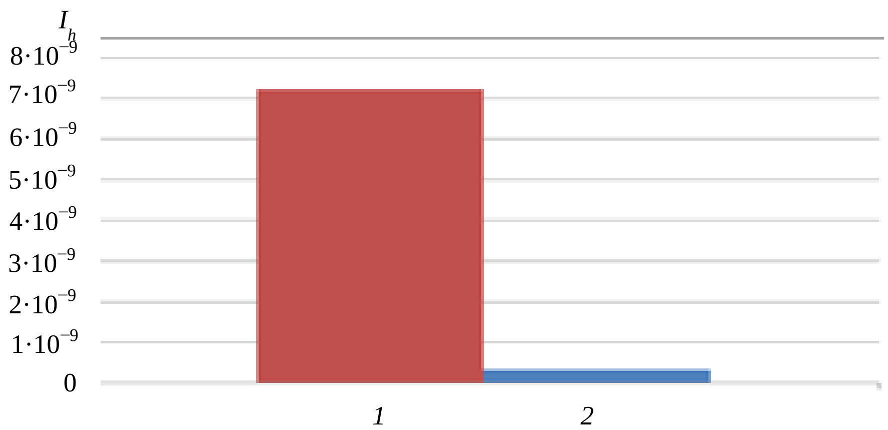

Fig. 10. The plot of wear rate as function of the rubber hardness and as function of the polyurethane hardness :
1 – IRP-1347 rubber; *2* – PU-80

It is seen from the graph (Fig. 8) that the lowest wear rate is demonstrated by IRP-1347 rubber. This means that this rubber is less susceptible to wear than REMAGRIP rubber. This allows using IRP-1347 rubber in aggressive environments.

The histogram of the rubber static friction coefficient (Fig. 9) shows that the studied rubbers have the required value of static friction coefficient for their use as the lining material for a drive drum. The static friction coefficient of IRP-1347 rubber is sufficient for using this material for drive drum lining [18].

7. Comparison of tribotechnical characteristics of rubber and polyurethane. As shown above, PU-80 polyurethane and IRP-1347 rubber used for lining the conveyor belt drive drum are less susceptible to wear.

The diagram (Fig. 10) shows that polyurethane demonstrates the lowest wear rate. This is due to the highest resistance to increasing temperature and load. PU-80 can operate at the load of above 50 N, while IRP-1347 rubber at the load of above 50 N starts to deteriorate.

Comparison the values of static friction coefficient of the studied materials shows that PU-80 has the lowest static friction coefficient.

Thus, the best material for lining the drive drum is PU-80.

The use of the polyurethane as a lining material allows to increase the maximum load on the product up to 4 times, and resistance to abrasive wear up to 10 times as compared to the rubber. Polyurethanes are among of the most abrasion resistant materials [19, 20].

Conclusion

1. Among all the tested polyurethane types, the maximum wear resistance is demonstrated by PU-80 grade polyurethane, which has the highest hardness, that ensures minimal contact deformations. Besides, this material has the required value of static friction coefficient.

2. Of all the tested rubber types, the maximum wear resistance is demonstrated by IRP-1347 rubber.

3. The comparison of the polyurethane and rubber showed that the best material for lining a conveyor belt drive drum is PU-80, since this material has the lowest wear rate compared to rubber, as well as the lowest static friction coefficient. Thus, PU-80 is the most suitable material that allows to recommend it for use for drive drum lining.

References

1. Alkhovik M. V. Mixture compositions containing secondary polyurethane. In: Alkhovik M. V., Kasperovich O. M., Petrushenya A. F. Disposal, recycling and processing of industrial waste. 2017, pp. 14-16 (in Russ.).

2. Sutkowsky W. W. Thennogravimetric study of rubber-waste polyurethane composites / W. W. Sutkowsky, A. J. Danch // Therm. Anal. and Calorim. 2004, vol. 78, iss. 3, pp. 905-921.

3. Katryuk I. S. Stream-flow transportation facilities. Designs, engineering, and operation. Textbook: Katryuk I. S., Musiyachenko E. V., Krasnoyarsk: KSTU Publ., 2006, 266 p. (in Russ.).

4. Czuprynski M. Elastomery poliuretanowe napelniane granulatem gumowy / M. Czuprynski // Polimery. 2004, vol. 49, no. 92, pp. 110-113.

5. Gadzhieva R. Sh. Problems and solutions of technological compatibility of polymer mixtures of polyamide, polyurethane and acrylonitrile-butadiene-styrene copolymer / Gadzhieva R. Sh., Kahramanov N. T., Guliyev A. M. Azerbaijan Chemical Journal, 2013, no. 4, pp. 80-86 (in Russ.).

6. Giles C. H. A general treatment and classification of the solute adsorption isotherm / C. H. Giles, D. Smith, A. Huitson // J. Colloid Interface Sci., 1974, vol. 47(3), p. 755.

7. Pat. USA 12/994692 (2013).

8. Vulcanized rubbers for articles working in liquid corrosive media. Technical requirements. GOST 071-76. Enacted as of 01/01/80. Moscow: USSR State Committee for Product Quality Management and Standards. State Standard of the USSR, 1976, 12 p. (in Russ.).

9. Kuzmina A. S. Composite materials made of waste rubber and polyurethane binders. / Kuzmina A. S., Balakin V. M., Litvinets Yu. I. / Plenary papers and abstracts of the 11th International Conference of undergraduate and graduate students "Synthesis, study of properties, modification, and processing of high-molecular-weight compound". Kazan, May 24-25, 2005, p. 224 (in Russ.).

10. Potentially improved and toughened polymeric products from fine metal powder – filled castor oil-based polyurethanes / Srivastava Anil, Singh Paramjit // 38th Macromolecular IUPAC Sumposium, Warsaw, 9-14 July, 2000: Book Abstr., vol. 3, Warsaw, 2000, p. 1200.

11. Golovanova K. V. Synthesis and physicochemical properties of aqueous polyurethane dispersions. / Golovanova K. V. [et al.]. Bulletin of the Technological University, 2017, v. 20, no. 13, pp. 18-22 (in Russ.).

12. Yagnyatinskaya E. Ya. Manufacturing technique, properties and features of use of rubber with fibrous fillers in industrial rubber goods./ Yagnyatinskaya E. Ya., Goldberg B. B., Leonov V. V. et al. M., TsNIITEneftekhim Publ., 1979, 54 p. (in Russ.).

13. Kim, B.K. Polym. Sei 54. 12 / B.K. Kim, Y.M. Lee, J. Appl. 1994. Pp. 1809-1815.

14. Levchenko N. I. Partnership of Polymers / N. I. Levchenko, S. A. Sukhorukova, T. V. Travinskaya // Churchill College, Univ. of Cambridge, 1996, pp. 195-200.

15. Kozhevnikova I. V. Polyurethane blend compounds containing waste dehumidifiers based on mineral oxides. Cand.Sci. (05.17.06 Engineering) Dissertation. Kazan, 2015, 178 p. (in Russ.).

16. LNK COMPANY [Electronic source]. Available at: http://www.lnkcom.ru/catalog/protective_coatings /lining_materials/lining_and_coating_of_driving_dr/remagrip_lining_tip_top_/). (acc. 07.11.2017).

17. Synthesis of polyether-based polyurethane-silica nanocomposites with high elongation property / Lee Sung-Il, Hahn Yoon Bong, Nahm Kee Suk, Lee Youn-Sik // Polym. Adv. Technol., 2005, Vol. 16, no. 4, pp. 328-331.

18. Varghese S. Morphology and mechanical properties of layered silicate reinforced natural and polyurethane rubber blends produced by latex compounding / S. Varghese, 1C0 Gatos., A.A. Apostolov, J. Karger-Kocsis // J. Appl. Polym. Sci. 2004, vol. 92, Nno. 21, pp. 543-551.

19. PC Polymer [Electronic source]. Access mode: http:/polimer-ug.com) (acc. 30.10.2017).

20. Ivanov E. I. Stelpant polyurethane lacquer coatings for corrosion protection in metallurgy. / Ivanov E. I., Ivanova A. E. Technology of wheeled and tracked vehicles, 2013, no. 3 (7), pp. 34-40 (in Russ.).

Библиографический список

1. Альховик М. В. Смесевые композиции с использованием вторичного полиуретана / М. В. Альховик, О. М. Касперович, А. Ф. Петрушеня // Обезвреживание, утилизация и переработка промышленных отходов. 2017. С. 14-16.

2. Sutkowsky W. W. Thennogravimetric study of rubber-waste polyurethane composites / W. W. Sutkowsky, A. J. Danch // Therm. Anal. and Calorim. 2004, vol. 78, iss. 3, pp. 905-921.

3. Катрюк И. С. Машины непрерывного транспорта. Конструкции, проектирование и эксплуатация: учеб. пособие / И. С. Катрюк, Е. В. Мусияченко. Красноярск: ИПЦ КГТУ, 2006. 266 с.

4. Czuprynski M. Elastomery poliuretanowe napelniane granulatem gumowy / M. Czuprynski // Polimery, 2004, vol. 49, no. 92, pp. 110-113.

5. Гаджиева Р. Ш. Проблемы и решения технологической совместимости полимерных смесей полиамида, полиуретана и акрилонитрил-бутадиен-стирольного сополимера / Р. Ш. Гаджиева, Н.Т. Кахраманов, А.М. Гулиев // Азербайджанский химический журнал. 2013. № 4. С. 80-86.

6. Giles C. H. A general treatment and classification of the solute adsorption isotherm / C. H. Giles, D. Smith, A. Huitson // J. Colloid Interface Sci., 1974, vol. 47(3), p. 755.

7. Pat. USA 12/994692 (2013).

8. Резины для изделий, работающих в жидких агрессивных средах. Технические требования: ГОСТ 071–76. Введ. 01.01.80. М: Государственный комитет СССР по управлению качеством продукции и стандартам: Государственный стандарт союза ССР, 1976. 12 с.

9. Кузьмина А. С. Композиционные материалы из отходов резины и полиуретановых связующих/ А. С. Кузьмина, В. М. Балакин, Ю. И. Литвинец / 1 Пленарные доклады и тезисы докладов 11 Международной конференции студентов и аспирантов «Синтез, исследование свойств, модификация и переработка ВМС». Казань, 24-25 мая, 2005. С. 224.

10. Potentially improved and toughened polymeric products from fine metal powder – filled castor oil-based polyurethanes / Srivastava Anil, Singh Paramjit // 38th Macromolecular IUPAC Sumposium, Warsaw, 9-14 July, 2000: Book Abstr., vol. 3, Warsaw, 2000, p. 1200.

11. Голованова К. В. Синтез и физико-химические свойства водных полиуретановых дисперсий / К. В. Голованова [и др.] // Вестник технологического университета. 2017. Т 20. № 13. С. 18-22.

12. Ягнятинская Е. А. Технология изготовления, свойства и особенности применения резин с волокнистыми наполнителями в РТИ / Е. А. Ягнятинская, Б. Б. Гольдберг, В. В. Леонов и др. М.: ЦНИИТЭнефтехим, 1979. 54 с.

13. Kim, B.K. Polym. Sei 54. 12 / B.K. Kim, Y.M. Lee, J. Appl., 1994, pp. 1809-1815.

14. Levchenko N. I. Partnership of Polymers / N. I. Levchenko, S. A. Sukhorukova, T. V. Travinskaya // Churchill College, Univ. of Cambridge, 1996, pp. 195-200.

15. Кожевникова И. В. Полиуретановые композиции, содержащие отходы осушителей на основе минеральных оксидов: дис. … канд. техн. наук: 05.17.06 / И. В. Кожевникова. Казань, 2015. 178 с.

16. LNK COMPANY [Электронный ресурс]. Режим доступа: http://www.lnkcom.ru/ catalog/protective_coatings/lining_materials/lining_and_coating_of_driving_dr/remagrip_lining_tip_top_/. Дата доступа 07.11.2017.

17. Synthesis of polyether-based polyurethane-silica nanocomposites with high elongation property / Lee Sung-Il, Hahn Yoon Bong, Nahm Kee Suk, Lee Youn-Sik // Polym. Adv. Technol., 2005, vol. 16, no. 4, pp. 328-331.

18. Varghese S. Morphology and mechanical properties of layered silicate reinforced natural and polyurethane rubber blends produced by latex compounding / S. Varghese, 1C0 Gatos., A.A. Apostolov, J. Karger-Kocsis // J. Appl. Polym. Sci., 2004, vol. 92, no. 21, pp. 543-551.

19. ПК Полимер [Электронный ресурс]. Режим доступа: http://polimer - ug.com /. Дата доступа 30.10.2017.

20. Иванов Е. И. Полиуретановые лакокрасочные покрытия Stelpant для защиты от коррозии на предприятиях металлургии / Е. И. Иванов, А. Е. Иванова // Технология колесных и гусеничных машин. 2013. № 3(7). С. 34-40.

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