TECHNICAL SCIENCES AND TECHNOLOGIES

UDC 678.7:621.855

DOI: 10.25140/2411-5363-2018-1(1)-48-57

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RESOURCE-SAVING TECHNOLOGIES OF MACHINE ELEMENTS PRODUCTION

Urgency of the research. *Most machines require perfection of their drives for the decline of resource-demanding and energy consumption at an acceleration and braking of drive elements. On making of such elements of drives, as gears, sprockets, chains, the third is expended and more than of labour intensiveness of production, necessary for the production of mechanisms and machines. Therefore a problem of decline of resource-demanding and energy consumption of drives application of polymeric compos is actual for the production of machine elements.*

Target setting. *Development and mastering of technological processes on the decline of resource-demanding and energy consumption of machine drives by application of polymeric materials instead of metallic.*

Actual scientific researches and issues analysis. *Efficiency of application of polymeric compos for making of polymeric machine elements is shown had an experience of exploitation of drives, equipped by such elements, both abroad and in a home engineer.*

Uninvestigated parts of general matters defining. *Philosophy of constructing and technology of polymeric machine elements on the concrete examples of the worked out constructions.*

The research objective. *Consideration of the worked out and made types of sprockets, gears and chains from polymeric compos from the point of view of their constructing and technology of making.*

The statement of basic materials. *Machine elements being produced on resource-saving technologies for mechanical engineering and can be used in the chain and gear drives which are a part of mechanisms of robots, polygraph, textile, food-processing, agricultural and other machines are considered. Some types of polymeric and metallic-polymeric chains, sprockets, gears are given. Integrated constructions, manufacturing and operation of machine elements out of polymeric composites are presented.*

Conclusions. *Application of integrated constructions of polymeric machine elements and their production for one technological operation casting under pressure on injection automatic machines enables cardinally (in times, but not on percents) to reduce labour intensiveness of production of machine elements, getting the row of advantages of structural, technological and operating character here.*

Keywords*: resource-saving technologies; polymeric and metal-polymeric sprockets; gears; chains.*

Fig.: 10. References: 10.

Introduction. At the basis of a modern technological civilization ability to make more and more products lays at their decrease material and energy consumption. The successful decision economic, energy and ecological problems is in many respects predetermined by application of new constructional materials, in particular, polymeric composites, for manufacture of machine elements [1].

In mechanical engineering machine elements of drives were traditionally made out of steel, that in many cases it is inexpedient. For example, chain drives, gears out of polymeric composites find more and more wide application thanks to high reliability and constructive simplicity in all areas of mechanical engineering, in particular, in robot-building, textile, polygraphic, food-processing, agricultural mechanical engineering. They possess necessary flexibility, work without vibrations, appreciably decreasing working noise, lubrication do not demand, are capable to amortize easy pushes and impacts, have smaller, than belt drives, dimensional and weight characteristics, and also can be used in wide enough range of speeds and loadings. Manufacturing of machine elements out of polymeric composites is little-waste and not very energy-consuming. From them is easier make machine elements of complicated shape, they are so technological, that give the chance to create the so-called integrated parts, which manufacture out of metal much more expensively or in general it is impossible. As density of polymeric composite materials several times below steel density, the moments of inertia of parts and energy consumption for speeding up and braking as consequence decrease that allows to raise frequency of rotation.

In view of limitation of energy and material resources the basic source of increase of the national income should become resource saving, i.e. the considerable volume of production should be made without a gain of material resources at the expense of their economy. Materials consumption a finished article – an end-product of multiphase process of its manufacture – includes the last work embodied in used materials. Than less material it is required for manufacturing of a concrete machine element, its design and the technology of production are especially perfect. To reduce materials consumption products it is possible, having raised quality of designing by optimization of their parameters, in particular, weight of constructions. The same purpose is served by application of new technological processes with high operating ratio of materials, volume forming machine elements for one technological operation, allowing receive not only ready elements without any subsequent processing, but also the integrated elements replacing with self of several elements of traditional manufacturing, based on serial processing of surfaces by cutting. Same increase of qualitative and functional characteristics of initial raw materials, its fuller use, including processing of a waste of the basic production promotes [2].

The laboratory of polymeric machine elements at chair of Machine Design Fundamentals CSTU had been carried out designing and introduction in a batch production on a number of the machine-building enterprises of Ukraine, Russia and Belarus driven and tension sprockets, gears out of polymeric composites. As a result of the conducted works losses from corrosion, vibrations and working noise (10-25 %) have been lowered metal and power consumption drives on 12-15 %, was reduced lathe park and floor spaces, labor productivity (at 6-10 time) has cardinally raised and the cost price of manufacturing of elements has decreased (on the average in 2,5 times), the operating ratio of materials to 0,95 as a result of application highly productive and little-waste technology of elements of drives by molding under pressure on injection automatic machines out of polymeric composites has raised [3, 4, 5].

The purpose of the present paper is to consider some sprockets, chains and gears out of polymeric composites according to its design and technology.

The statement of basic materials.

Design philosophy. Manufacturing of chain drives and their elements out of polymeric composites according to the constructions similar metal, in most cases is impossible because of differences in technological and physical-mechanical properties of materials. The method of structurally functional designing has been applied to creation of constructions of elements of chain drives with necessary technological and operational characteristics [5].

Designing of chain drives elements out of polymeric composites is closely connected with designing of molds for their injection molding under pressure on injection automatic machines and technology of processing of polymeric materials in a product [6, 7, 8]. Presented further design of sprockets and chains out of polymeric composites are shown that its design philosophy differ first of all by application of elastic deformation polymeric materials. Links of the offered design can be made by injection molding under pressure on injection automatic machine out of polymeric composites during one technological operation.

The basic requirements shown to constructions of machine elements out of polymeric materials, produced by injection molding under pressure, look as follows.

1. A machine element should have technological biases.
2. In machine elements undercuts are inadmissible.
3. Tolerances should be technically proved, i.e. are calculated taking into account physical-mechanical characteristics of applied materials.
4. Elements, whenever possible, should not have cantilever portions.
5. The shape of machine elements should to provide, whenever possible, application of all-in-one matrixes and punches.
6. The configuration of machine element should not inhibit to free filling of a die-casting mould by melt.
7. The most responsible elements, whenever possible, should not get to a plane of the parting mold.
8. The machine element should have the roundings off necessary for increase of mechanical strength, simplification of process forming and appearance improvements.
9. Webs should be probably thin and an equal thickness.

Except these requirements, at creation of new constructions of chain drives elements possibility of execution of machine elements integrated was used, i.e. one monolithic element produced for one technological operation, can include the maximum number of structurally functional elements. So, at designing and manufacturing of chains their links represented monolithic machine elements.

After creation of basic constructions design parameters of created elements at which definition possibility of their work together with standard elements of chain drives was pawned have been established. It became for the purpose of a possibility of their further use in the available equipment and for reception of more exact comparative characteristics. Such design parameters are: a chain step, the shape and the sizes of elements of engagement, distance between internal plates. They coincided with corresponding elements of roller chains in accordance with ГОСТ 13568-75 and sprockets in accordance with ГОСТ 592-81. The corresponding equipment for manufacture of links of chains and sprockets of the developed constructions by injection molding method under pressure on injection automatic machines has been made. Chains made out of polymeric composites based on polyamides, have the dimensional precision corresponding to precision driving roller chains of a general application with small breaking force, and chains out of glass-filled marks have higher precision characteristic for chains at which assemblage apply a selective method.

Practice of chain drives operation shows, that in overwhelming majority of cases the useful tension of standard metal chains makes 10-20 % from their limiting (destroying) loading. Therefore it makes sense to make not only sprockets, but also chains from polymeric composites. They, though do not possess such ultimate load as metal chains, however, not only satisfy often to the most widely distributed conditions of operation, but also have advantages in weight, consumption of energy, speed, low level of noise, anticorrosive firmness and lubrication.

Chains out of integrated elements. As it has appeared, manufacturing of chain drives and their elements out of polymeric composites according to the constructions similar metallic (fig. 1), in most of cases it is impossible because of differences in technological and physicomechanical properties of materials. The connections with tightness which are used practically all metallic chains, cannot be used for assemblage of chains out of polymeric materials because of easing press fits owing to a relaxation of stresses, characteristic for polymers. Besides, owing to dimensional closed state of a construction of a roller chain the increase in dangerous cross sections of plates in places of ears without substantial growth of dimensions (width) of a chain is impossible, that for chains out of polymeric materials is of great importance owing to lower strength and rigidity of constructional polymeric materials in comparison with the steels traditionally applied for this purpose.

Fig. 1. Inner (a), external (b) links and design of the standard steel roller chain

Except the requirements shown to constructions of machine elements out of polymeric materials, made molding under pressure, at creation of new constructions of chain drives elements provided possibility of execution of machine elements integrated, that is one monolithic element produced for one technological operation, can include the maximum number of structurally functional elements [9].

Further some standard sizes of machine elements out of polymeric composites on the basis of polymers of polyamide group are resulted developed in polymeric machine elements laboratory of CSTU.

Instead of six metal elements of which the link standard roller driving chain consists (fig. 1), it is made one monolithic link out of polymeric composite (fig. 2).

On fig. 2 the monolithic link of a chain in two projections, where 1 - ledges is represented; 2 – a working part of a hole; 3 – head, consisting of a hat (a) and leg (б); 4 – a hole for assemblage; 5 – symmetrically located bent plates; 6 – the roller. Size *L* gets out such that height *H* of ledges allowed to carry out assemblage.

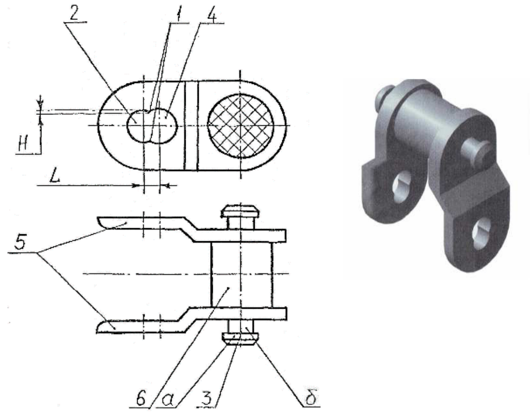

Fig. 2. Elastic monolithic link of a chain

Fig. 3. Chain out of elastic monolithic links

The corresponding equipment for manufacturing of links of chains and sprockets of the developed constructions by molding under pressure has been made.

The chains made out of polymeric composites, based on polyamides, have the dimensional precision corresponding to precision of driving roller chains of a general application with a small ultimate load, and chains out of glass-filled types have higher dimensional precision, corresponding to chains at which assemblage apply a selective method.

Only elastic deformations thus take place. In each of plates the special holes formed by two arches of various radiuses which centers do not coincide are carried out and lay on a longitudinal axis of a link. One of arches (smaller radius) is the worker, and the second (larger radius) serves for realization of assemblage of a chain. The centers of the arches forming holes are a little dissolved for formation of ledges which prevent from spontaneous dismantling of a chain. Diameter of an arch of a working part of a hole 2 and leg of head 3б are equal among themselves, and also diameters are equal: the greatest cap of head 3a and arches of a holes 4 larger radius. Chain assemblage is carried out as follows: the link is inserted by turns the heads between deformed plates of the following link. Caps of heads 3a are inserted into holes 4 (in places larger radius), and plates pass in undistorted state. By longitudinal force the heads are entered into a working part of a hole, it is elastic deforming thus ledges 1 in the middle of a hole. These ledges prevent from spontaneous dismantling of a chain.

On fig. 3 the chain with elastic monolithic links is shown. It is important to note that of such links as is shown on fig. 2 it is possible to assemble two-, three- and multiple-row chains. Example of such chains is shown on fig. 4. To use chains with elastic monolithic links on the available equipment and not to create for them special sprockets, it is necessary, that external diameter of pins was equal to diameter of rollers driving chains of type ПР according to ГОСТ 13568-75 corresponding steps. Sizes of diameters heads and radiuses of the arches forming holes in plates, can change in certain limits depending on physical-mechanical properties of an applied polymeric composite.

On fig. 4 it is shown also metal-polymeric chain which inner links are executed out of a polymeric composite in the form of one integrated monolithic machine element consisting of two cylindrical elements with holes, connected by plate-like elements, and external links in which role standard metal connecting links can serve, i.e. such chain is completely dismountable.

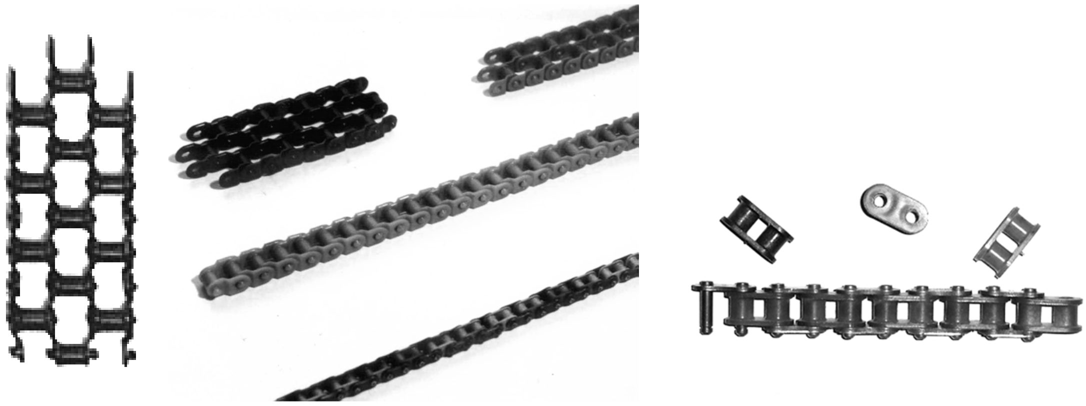

Fig. 4. Polymeric three-, two- and one-row chains (left and middle). Metal-polymeric single-row (right) with integrated monolithic inner links

On fig. 5 the chain consisting of monolithic inner links 1, external links of 2 and stainless steel coupling rods 3 is represented. Plates of links are executed by straight lines for giving of possibility of increase in their thickness without loss of ability to their assemblage in a uniform chain. Thus at assemblage the principle of elastic deformation of links is not applied any more. It is reached by introduction in a chain of a modular external link 2 which is fixed in a chain by means of the coupling rod 3, simultaneously incorporating with an inner monolithic link 1. The stress-strained state, contact stresses and other questions concerning such chains are considered in [3; 5].

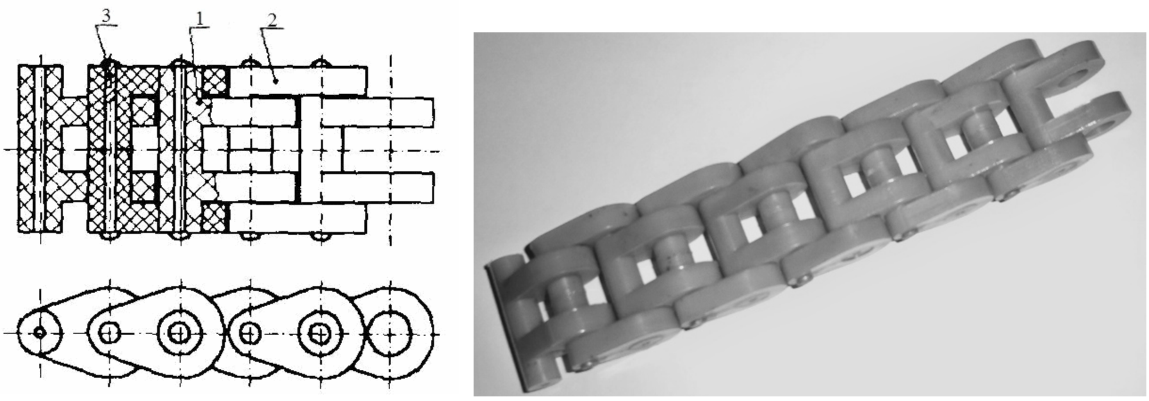

Fig. 5. Driven metal-polymeric chain

Integrated sprockets and gears. Deformation of a polymeric sprocket in case of the application of loading to one tooth extends and on the next teeth located both in a direction, and against a direction of rotation of a sprocket. Essential change of the stress-strained state in a body of a sprocket depending on the shape of teeth, radius of a transitive zone at a hollow is observed. Constructive changes of a sprocket for the account of introduction of thickenings of a zone of fit to a shaft lead to essential redistribution of stresses and deformations and decrease extreme stresses on an external surface of a tooth and in a sprocket body approximately in 1.5 times. A critical zone in a sprocket body is all hollow of toothed rim, and not just a working surface of a tooth, as at usual rigid metal sprockets.

Designing of sprockets from polymeric composites is a some complicated because the sizes of toothed rim are limited by the sizes of a chain, and it is impossible to increase its strength for the account of increase in width of a tooth (as in case of a gear). It is necessary to consider also the profile shape a tooth which appreciably defines as much as possible admissible speed of movement and service life of a chain and sprockets. At operation of the chain drive equipped with sprockets from polymeric composites, it is necessary to give advantage to the profile shape according to ГОСТ 592-81 (rectilinear) before the profile shape it agree ГОСТ 591-69 (concave-convex) for some reasons, basic of which is ability of a rectilinear profile to compensate the maximum increase in a step of a chain as a result of its wear without engagement breaking.

For guarantee rigidity and prevention warping in a machine element design rigidity edges are provided. And it is necessary to notice, that rigidity edges in many cases are necessary not only at operation to resist to deformations, but also at extraction of machine elements from the form. Besides, rigidity edges are used for management of process of filling of a making out cavity and compulsory orientation melt in a necessary direction. For example, at casting of sprockets, gears or pulleys accordingly chain, gear and tooth-belt drives of an edge of rigidity in a radial direction are necessary not only for maintenance of durability of machine elements and reduction of a thickness of casting, but also for the accelerated direction of a stream melt for the purpose of qualitative formation of a gear wreath, and from both parties of a disk, differently such machine element will have defects of teeth and propensity to warping.

On fig. 6 photos of some standard sizes of polymeric machine elements, illustrating both told above, and results of research of their is stress-strained state are resulted. Let's notice, that it is possible to operate by stress-strained state of a design by its purposeful change rigidity (thickness of a toothed rim, a nave, quantity of ribs and their arrangement, application of spokes instead of ribs, saving thus a material, etc.) depending on the requirements shown by conditions of operation of chain drives.

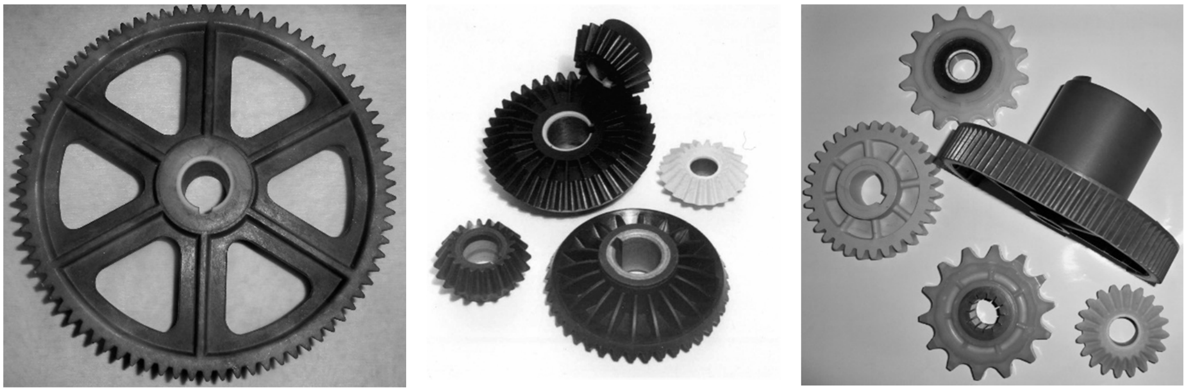

Fig. 6. Polymeric sprockets and gears

On fig. 7 is shown the example of one of the integrated sprockets, including, except actually sprocket, a drum and a cover for bracing.

Designs of forms are various, as products for which manufacture they are intended are various. Any form represents a combination of known knots and details to knots and special purpose details. Performance of cooling system for each compression mould considerably raises equipment cost. Therefore, if there are no obstacles, project the universal cooling block providing working capacity of replaceable packages, including forming and pushing out systems.

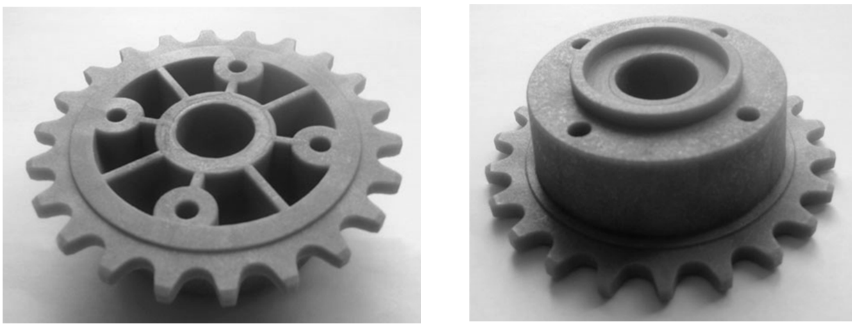

Fig. 7. Sprocket integrated with drum and cover of bracing

The way of manufacturing of matrixes is a determinative at manufacturing of compression molds. The most widespread way of manufacturing of matrixes − milling with the subsequent polishing cannot provide sufficient accuracy, application of more progressive technologies therefore is necessary. One of them is electro-erosion processing of metals. At manufacturing of matrixes by this way preliminary operations − milling and thermal processing are used. Using this preliminary operation, we receive a gain in time as on productivity on simple operations the electro-erosion technology concedes to milling. The remained allowance remove on a draught mode with the big energy of an impulse, and in process of allowance reduction pass to softer modes.

On fig. 8 the example of a cut out form-building teeth of a sprocket of a matrix by a wire electrode on the electro-erosion machine tool with numerical programmed control and a corresponding sprocket is shown.

Fig. 8. Cut out of a matrix and cast sprocket

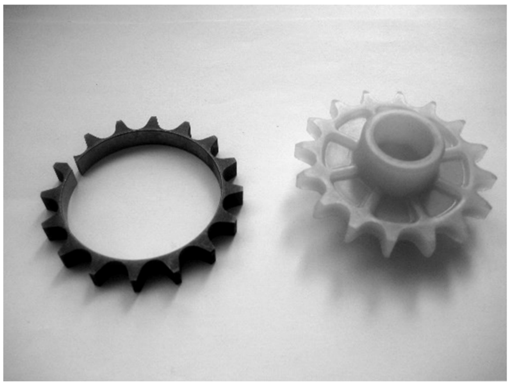

Fig. 9. Tension 3-row sprocket and idle gear wheel

Thus the big clearance on fig. 8 in comparison with diameter of a wire electrode (0.2 mm) speaks liberation of elastic deformations.

Manufacturing of matrixes for sprockets, gear wheels and similar machine elements it can be carried out on electro-erosion machine tools with the numerical program management of types 4531Ф3, 4532Ф3, 4732Ф3, Agiecut, which make a cutting a wire electrode form-building gear wreaths of matrixes on parameters preliminary entered into the program.

Other progressive method of reception of matrixes of compression moulds of a complicated configuration is the plasma dusting on model of a working layer in the thickness 1…3 mm with the subsequent registration of a basic part by pouring by other metals («bark-like» method). As a result labor input of manufacturing of equipment reduces in 3…10 times, and the working surface of a matrix does not demand finishing processing as cleanliness of a surface corresponds to cleanliness of a surface of model. Average time of manufacturing of a working layer makes 5…30 minutes, hardness reaches it 72HRC.

Base materials for creation of polymeric composites are polyamides PA-6 and PA-6.6 manufactures of Chernigiv joint-stock company «Chemical fibre». As a result of their updating by different functional additives their physicomechanical properties cardinally improve.

Because of fibre glass presence in a composite material there is a deterioration of matrix group elements. To reduce its influence, these elements are chrome plated with thickness of a covering till 18-20 mc and polished for giving of a demanded roughness of a surface.

The complicated configuration of a sprocket or gear wheel dictates the form of elements of matrix group. As a result of casting of an experimental batch of polymeric machine elements modes of molding are fulfilled and there are data for management in technological parameters of manufacturing of a polymeric machine element (pressure of injection of a material, temperatures of processing of a material on zones, compression mould temperature, temperature melt, speed of rotation screw, time of a cycle of a machine element manufacturing). Use of such technological parameters as the data carriers, adapted for input possibility in management injection automatic machine, creates possibilities for computerized manufactures of machine elements by molding under pressure out of polymeric composites [4]. Except technological advantages, polymeric elements of chain drives have also operational advantages [9; 5].

Low heat conductivity of polymeric materials promotes accumulation of heat in a machine element, the local overheat in places of concentration of a thermal stream [10], for example, interfaces of naves of idle gear wheels and tension sprockets to motionless axes therefore can take place. Besides intensity of stresses in such interfaces can exceed that in teeth under the influence of loading. All it leads to thermal destruction a polymeric material, as an example of that fig. 9 where are shown a tension sprocket for the three-row chain, working in oil, and a parasitic gear wheel can serve [5].

As heat accumulation occurs in a machine element, artificial heat removal, for example, having blown in surfaces air seldom gives desirable effect. More effective in this case is division of a thermal stream by means of flutes and other constructive decisions (ribbing, a thin nave) on purpose non-admission local overheats in a machine element.

On fig. 10 three different constructions of polymeric sprockets are presented: in the first of them division of a thermal stream by means of flutes (at the left) is applied, and the bearing of sliding from a self-greasing material CAM is built in an sprocket from polyamide PA-6; in another (in the centre) the same flutes are applied, but the bearing of sliding and an sprocket are made of one antifriction material for one technological operation; in the third sprocket the thin nave, and figured apertures round it (on the right) is applied also give the chance to regulate fastening of this sprocket for the purpose of installation of a necessary phase lag in an operating time of chain transfer. In all three cases also it is applied ribbing surfaces to heat exchange intensification.

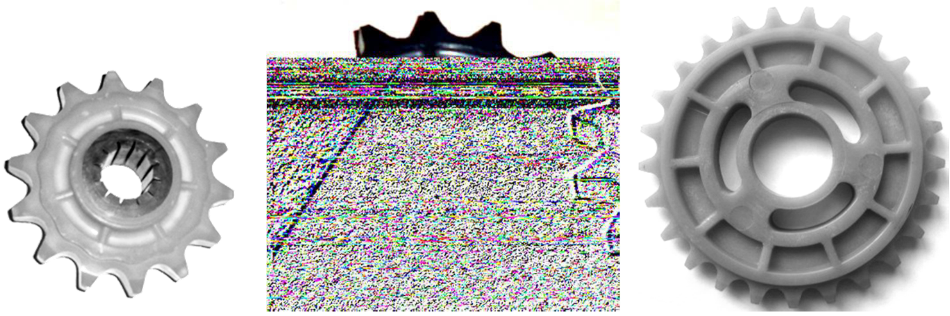

Fig. 10. Tension sprockets of different constructions with separation of heat stream

Conclusion. The presented examples of machine elements out of polymeric composites allow to draw a conclusion that application of integrated machine elements constructions and their manufacturing for one technological operation by molding under pressure on injection automatic machines gives possibility cardinally (in times, instead of for percent) to lower labor input of manufacturing of machine elements, receiving thus a number of advantages of constructive, technological and operational character.

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УДК 678.7:621.855

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РЕСУРСООЩАДНІ ТЕХНОЛОГІЇ ВИРОБНИЦТВА ДЕТАЛЕЙ МАШИН

Актуальність теми дослідження. *Більшість машин потребує вдосконалення їхніх приводів для зниження матеріаломісткості та енергоспоживання під час розгону і гальмування приводних деталей. На виготовлення таких деталей приводів, як шестерні, зірочки, ланцюги, витрачається третина і більше трудовитрат, необхідних для виробництва механізмів і машин. Тому є актуальною проблема зниження матеріаломісткості та енергоспоживання приводів застосуванням полімерних композитів для виробництва деталей машин.*

Постановка проблеми*. Розробка і освоєння технологічних процесів по зниженню матеріаломісткості та енергоспоживання приводів машин шляхом застосування полімерних матеріалів замість металевих.*

Аналіз останніх досліджень і публікацій*. Ефективність застосування полімерних композитів для виготовлення полімерних деталей машин продемонстрована наявним досвідом експлуатації приводів, оснащених такими деталями, як за рубежем, так і у вітчизняному машинобудуванні.*

Виділення недосліджених частин загальної проблеми. *Філософія конструювання і технології виготовлення полімерних деталей машин на конкретних прикладах розроблених конструкцій.*

Мета статті. *Розгляд розроблених і виготовлених типів зірочок, шестерен і ланцюгів з полімерних композитів з погляду їх конструювання і технології виготовлення.*

Виклад основного матеріалу*. Розглянуті деталі машин, які розроблені і виробляються за ресурсоощадними технологіями для машинобудування, і можуть бути застосовані в ланцюгових та зубчастих приводах, що є частиною механізмів роботів, поліграфічних, текстильних, харчопереробних та інших машин. Дані деякі типи полімерних і металополімерних ланцюгів, зірочок, шестерен. Представлені інтегровані конструкції, виготовлення та функціонування деталей машин з полімерних композитів.*

Висновки відповідно до статті*. Застосування інтегрованих конструкцій полімерних деталей машин і їх виробництво за одну технологічну операцію литвом під тиском на термопластавтоматах дає можливість кардинально (в рази, а не на відсотки) знизити трудомісткість виробництва деталей машин, отримуючи при цьому ряд переваг конструктивного, технологічного та експлуатаційного характеру.*

Ключові слова: *ресурсоощадні технології; полімерні та металополімерні зірочки; шестерні; ланцюги.*

Рис.: 10. Бібл.:10.

УДК 678.7:621.855

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РЕСУРСОСБЕРЕГАЮЩИЕ ТЕХНОЛОГИИ ПРОИЗВОДСТВА ДЕТАЛЕЙ МАШИН

Актуальность темы исследования. *Большинство машин требуют совершенствования их приводов для снижения материалоемкости и энергопотребления при разгоне и торможении приводных деталей. На изготовление таких деталей приводов, как шестерни, звездочки, цепи, расходуется треть и более трудозатрат, необходимых для производства механизмов и машин. Поэтому представляется актуальной проблема снижения материалоемкости и энергопотребления приводов применением полимерных композитов для производства деталей машин.*

Постановка проблемы*. Разработка и освоение технологических процессов по снижению материалоёмкости и энергопотребления приводов машин путём применения полимерных материалов взамен металлических.*

Анализ последних исследований и публикаций*. Эффективность применения полимерных композитов для изготовления полимерных деталей машин продемонстрирована имеющимся опытом эксплуатации приводов, оснащённых такими деталями, как за рубежом, так и в отечественном машиностроении.*

Выделение неисследованных частей общей проблемы. *Философия конструирования и технологии изготовления полимерных деталей машин на конкретных примерах разработанных конструкций.*

Постановка задачи. *Рассмотрение разработанных и изготовленных типов звёздочек, шестерен и цепей из полимерных композитов с точки зрения их конструирования и технологии изготовления.*

Изложение основного материала. *Рассмотрены детали машин, которые производятся по ресурсосберегающим технологиям для машиностроения и могут быть использованы в цепных и зубчатых приводах, являющихся частью механизмов роботов, полиграфических, текстильных, пищеперерабатывающих и других машин. Даны некоторые типы полимерных и металлополимерных цепей, звёздочек, шестерен. Представлены интегрированные конструкции, изготовление и функционирование деталей машин из полимерных композитов.*

Выводы в соответствии со статьей. *Применение интегрированных конструкций полимерных деталей машин и их производство за одну технологическую операцию литьём под давлением на термопластавтоматах даёт возможность кардинально (в разы, а не на проценты) снизить трудоёмкость производства деталей машин, получая при этом ряд преимуществ конструктивного, технологического и эксплуатационного характера.*

Ключевые слова: *ресурсосберегающие технологии; полимерные и металлополимерные звёздочки; шестерни; цепи.*

Рис.: 10. Библ.: 10.

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