Ensuring the processability of construction disposal during design

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Abstract. The level of organization of recycling and recycling processes in Russia has been assessed. The questions of the level of consumption of resources in production are presented, which gives an idea of the potential possibilities of unification not only of design solutions, but also of the nomenclature of used materials. It has been established that technological efficiency of recycling provides not only reduction of total costs for the recycling process itself, but also allows to more fully use the potential of working capacity of parts laid down during their production. The possibilities of ensuring the processability of the product design during its disposal at the design stage are considered. One of the most effective methods of ensuring the processability of the structure during recycling is to use the system of repair kits during design, which allows simultaneously increasing the processability during production, operation and repair. The proposed approach makes it possible to significantly reduce not only the time spent in repair of ground-based transport and technological means (GTTM), but also to significantly realize the possibility of providing technological effectiveness in recycling GTTM themselves and their units and parts. The use of repair kits formed at the design stage allows increasing efficiency not only during maintenance and during repair of GTTM, but also during their utilization and recycling.

1. Introduction
The formation of Russia as a technologically developed power and its integration into the global economy will be impossible without the introduction and improvement of methods of efficient and environmentally sound use of natural and technogenic resources. This problem can be solved only by creating closed low-waste cycles, as well as by stimulating and providing technical support for the integrated use of secondary resources generated in the production and consumption processes. The less garbage in the country, the cleaner and safer it is for human habitation, the richer and stronger on the world stage.

Extensive growth in resource consumption has already led to a certain raw material dependence in the economies of many countries, including Russia, and to the aggravation of environmental problems associated with the environmental impact of the extraction of raw materials, production and the need to solve the problem of final disposal of production and consumption waste.

2. Problem statement
Continuous development and improvement of the vehicles design, which include: cars and trucks, buses, special communal vehicles on an automobile and original chassis, construction and road vehicles, vehicles for servicing aircraft and maintaining airports, etc. leads to saturation of the consumer market, and in some areas to glut.
This is directly related to the increasing consumption of natural resources, as can be seen from the data presented in Fig. 1.

Moreover, the efficiency of the use of consumed resources is close to 0. For example, for the manufacture of 1 ton of parts and assembly units used in a car, 150 tons of natural substances are processed, i.e. of each 1 ton of the natural substances in the car remains – 0.7 %. The remaining 99.3 % is wasted.

This situation poses a challenge for designers to increase the efficiency of the use of minerals. The service life of these machines varies from 5 to 30 years, but in any case, the question arises that the operation ends sooner or later and there is an acute question of the disposal of units and materials from which they are made.

The only thing that is not logical in this process is the late-arising question – what to do with the remains of machines.

For example, at the beginning of 2016, about 1,500 million tons of toxic production and consumption waste were accumulated at enterprises in various industries. About 90 million tons of toxic industrial waste (IW) are generated annually at enterprises of the Russian Federation, of which 87 million tons are classified as hazard classes III and IV. The amount of consumer waste, or municipal solid waste (MSW), is increasing annually in Russia by 30 million tons.

In 2016, enterprises used in their own production about 40 million tons (40 %) and completely neutralized 9 million tons (10 %) of the total amount of waste generated over the year. The remaining waste was transferred to landfills for disposal.

An analysis of the nomenclature of the materials used (see Table 1) in the manufacture of machines for leading machine manufacturers showed all their diversity and the difficulty of solving the problem of ensuring their disposal, taking into account the need to comply the efficiency and environmental friendliness of these processes.

Data analysis of table 1 makes it possible to conclude that the disposal of machinery is not only a reduction in environmental pollution, but also a reduction in the consumption of natural resources and energy. The environmental and economic effect of the utilization of vehicles consists of:

- the economic component, including cost reduction in the secondary use of materials and the associated decrease in the production of materials from fossil natural resources, reduction in energy consumption;
- environmental component, including reduction of pollution of soil, water, atmospheric air from the effects of abandoned and not recycled cars, reduction of environmental pollution when used in the production of recycled materials.
Table 1. Materials used in the manufacture of automobiles

| Name of material | Material content in a typical automobile, % of weight | USA | Japan | Europe |
|------------------|------------------------------------------------------|-----|-------|--------|
| Steel and iron   |                                                      | 67  | 72.2  | 65     |
| Plastics         |                                                      | 8   | 10.1  | 12     |
| Glass            |                                                      | 2.8 | 2.8   | 2.5    |
| Rubber           |                                                      | 4.2 | 3.1   | 6      |
| Liquids and oils |                                                      | 6   | 3.4   | 2.5    |
| Nonferrous metal |                                                      | 6   | 6.2   | 8      |
| Other materials  | (paint, insulation, wiring)                         | 4   | 2.2   | 4      |
| Weight, kg       |                                                      | 1438| 1270  | 1185   |

The product life cycle ends with the disposal phase. For cars and tractors (especially cars), the relevance of safe disposal is increasing every year, as the number of used cars grows, and existing car dumps are overcrowded and poison the atmosphere. Therefore, the international community establishes uniform principles to address this problem. Thus, the European Union Directive 2000/53 / EU “Decommissioned vehicles” and the Commission Directive dated March 30, 2011/37 / EU amending Appendix II to Directive 2000/53 / EC establish:

- participating countries shall take the necessary measures to organize in their territory a sufficient number of points of reception for used cars and create a system for recycling and disposal of old cars and worn-out components;
- no later than January 1, 2006, all vehicles that are out of service must be disposed of at least 85 % of the total mass, and the level of reuse of parts and recycling of materials must be at least 80 % of the mass of the car (without burning).

Therefore, at the stage of design preparation for the production of a new product (automobile, road vehicle and their components), it is necessary not only to evaluate, but also to constructively ensure the processability at the design stage.

The processability of disposal is determined by the following key indicators:

- the time of disassembling the product into its component parts;
- the possibility of reuse of parts in order to ensure the development of the full resource inherent in them during production;
- nomenclature of the used connections, unification of threaded connections;
- the number of tools required for disassembling;
- the time necessary for drainage (i.e., freeing the vehicle of fuel, grease, brake and coolant, etc.);
- the time of sorting by groups of materials for the application of various recycling processes and the suitability of parts for reuse.

In various works, as one of the criteria, it is proposed to use, for example, specific indicators of dismantling manufacturability. This is the ratio of the mass of the dismantled unit, part, set to the time spent on dismantling.

However, the use of this indicator has some difficulties, since a car, for example, combines, as mentioned above, a large number of materials of various nature, the specific weight indicators of which are also varied, and the complexity of dismantling, for example, steel parts does not differ much from the complexity of dismantling parts from polymers, which is quite clearly seen in Fig. 2.

Due to the characteristics of polymeric materials, which have significantly worse recycling characteristics, the operations of dismantling plastic, rubber, and electrical products (including electronic) from mixed materials are separately considered and analyzed.
Also, some authors consider the hierarchy of application of fasteners optimal from the point of view of optimization of disposal, which is given in table 2.

Priority is for the use of fasteners for automotive components.

### Table 2. Types of Recommended Compounds

| Priority Sequence Number | Connection type                  | Name of fasteners                                                                 |
|--------------------------|----------------------------------|-----------------------------------------------------------------------------------|
| 1                        | Quick couplings                  | Magnetic, Velcro, latch, clip, ¼ or ½ turn fasteners, button, clasp, clips, pin   |
| 2                        | Detachable connections           | Screw, bolt, nut with convenient heads of the same size for the tool and accessibility for power tools. Adhesive joints (gluing), allowing to quickly separate parts without the use of tools. Screw, bolt, nut with heads of several sizes, requiring replacement of the tool with accessibility for electric pneumatic tools. Screw, bolt, nut with heads of several sizes with difficult accessibility for power tools |
| 3                        | One-piece connections            | Rivet, soldering, welding, gluing, foaming, thermal shrinkage                      |

Thus, simplifying the disassembly of the product into its components, reducing the dismantling time, reducing the drain time of all liquids and oils used in the operation, using environmentally friendly materials, etc., the designer can increase the processability of the car during disposal at the design stage.

### 3. Problem solving methods

Ensuring the processability of the product is a multifaceted work to improve the design of the machine as a whole, its individual components and parts with the goal of the most rational production, maintenance, repair and disposal.

Ensuring the processability of the design is laid at the very early stages of design. The following tasks are solved:

- technological control of design documentation;
- assessment of the level of processability of the design;
• development of the design for processability;
• design changes.

Each of these tasks needs to be addressed, both in relation to the product as a whole, and to individual assembly units, parts and blanks.

Therefore, it is extremely important to carry out the design development for processability at the early stages of design, when the huge cost of funds for the technical preparation of production has not yet been made. Otherwise, the design will have to be "adjusted" for the already purchased and installed equipment, which can significantly reduce the service (functional, consumer) quality of the product, in particular a car, road-building machine, tractor or their individual units and parts, or purchase new equipment.

The processability of the product design during disposal is manifested in operations such as preparation for decommissioning, disassembly of the product, transportation, storage and disposal. In preparation for decommissioning and disassembly, the main attention is paid to the environmental characteristics of the product (radioactivity, the separation of materials by brand, weight and size) of the components of the product.

Therefore, the product designed by the constructor must meet the requirements not only of its functional purpose, but also of the processes of its manufacture (assembly, preparation of blanks, manufacturing of parts), maintenance, repair and disposal.

Ensuring the processability of the product design is carried out at the level of parts, assembly units and the product as a whole. The most general requirements for processability of product design:

• rationality of the division, layout of products and their components;
• widespread use of the principles of constructive and technological continuity, unification, standardization and simplification;
• rational limitation of the number of grades and assortments of materials used;
• widespread use of non-deficient materials and materials, the processing of which does not cause difficulties;
• rational designation of tolerances and roughness parameters of the machined surfaces;
• ensuring the convenience of basing parts in the product and workpieces during their processing and, if possible, achieving sufficient structural rigidity;
• compliance with the conditions ensuring the simplification of assembly work and the possibility of their mechanization and automation;
• creation of parts of such structural forms that allow the use of more productive processing methods and the use of high-performance equipment;
• reducing the variety of types of machined surfaces and geometric dimensions of the same type of structural elements of the part;
• the maximum possible simplification of the design of assembly units and parts;
• the possibility of using advanced technological processes, high-performance equipment and more advanced methods of labor organization, which requires the presence of certain structural elements in parts or assembly units;
• ease of maintenance and repair during operation, which requires the introduction of certain elements into the design.

Based on the requirements formulated above for the processability of the product’s design from the standpoint of ensuring its more efficient disposal, it is necessary to consider some problems that can only be effectively solved at the design stage of the machine.

To reduce the costs of various types of dismantling during disposal, it is necessary to design the principle of forming repair kits in the design of machines, the use of which will not only optimize the time required for disassembly, but also ensure a more complete use of the resource of each part of the kit and the machine as a whole.

In accordance with [1], a product repair kit is a combination of its assembled parts, united by functional unity, forming a closed dimensional group with full technological completeness. The
closure of the group is realized, for example, in the fact that when it is installed in the product, it forms a closed dimensional chain with the accuracy parameters of the Assembly size within the standard.

From the definition of a repair kit, it follows:

• replacement of the repair kit with the corresponding new (repaired) repair kit should not require additional technological operations to completely restore its functional properties and reliability of the product;

• in contrast to a detailed replacement, a complete replacement does not destroy (does not worsen) due to repair actions the functional work and reliability indicators of the unit as a system.

In accordance with the definition introduced, if the product has more than one repair kit, then the product’s repair kits must be independent in aggregate, i.e. the operability of any of the repair kits of the product does not depend on whether or not any combination of its other kits has failed.

Thus, the proposed system of repair kits provides not only compliance with the principles of processability of product design during design and production, but also provides optimal conditions for the operation, maintenance, repair and disposal of machines at the end of their term of use [2].

Another no less important area for improving the processability of product design is the wider use of the potential applications of polymer materials, not only for gluing machine parts, but for the fundamental replacement of the conditions for their connection with each other, for example, the use of shaft-sleeve retainers, threaded retainers, and liquid gaskets.

The most promising direction of ensuring the processability of the design of products in this direction is the use of shaft-sleeve retainers, which not only interconnect mating parts, but also allow you to fundamentally change the conditions of such connections [3].

It is known that today, constructors widely use one-piece connections (interference fit) or key and splined connections to transmit torque.

The first type of joints is characterized by the creation of additional internal stresses in the details, which leads to an increase in their stress-strain state and, as a consequence, a decrease in their service life and the inability to continue to use them at all, or necessitates additional technological operations to restore their operability. And this is an additional time and money cost [4].

In the second case, it is necessary to carry out additional machining of the surfaces to be joined under the key or slots and to ensure the production of additional parts – keys.

Such joints are based on landings with a gap (or transitional ones), and this, in turn, leads to accelerated wear of such joints and serious problems in restoring their operability, that is, causes problems of further efficient use of their resource.

4. Conclusion

The use of shaft-sleeve retainers to replace such joints allows not only to reduce costs during their manufacture and assembly, but also during disassembly and makes it possible to more deeply use their working capacity, while unconditionally ensuring the quality of the assembly joint [4].

Consideration of the possibilities of applying modern and promising materials and methods in the design of products will certainly provide an increase in the processability of the design of products not only for operation, but also for the disposal of machines after the end of their service life.

In our opinion, the most promising direction for improving the processability of the design of products is the replacement of metal parts with parts made of polymeric materials. This replacement is especially relevant for parts of friction pairs, for example, camshaft support bushings or plain bearing shells for crankshafts.

Today, the physicomechanical properties of composite materials are no worse than the properties of metals, and often, in terms of the main parameters characterizing the performance of friction pairs, they exceed them substantially.

References

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