DESIGN OF AUTOMOTIVE CONSTRUCTIONS BASED ON INTERIOR AND BODY OUTFIT OF OFFROAD CAR

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Abstract

Travelling off the road requires an adequate vehicle. The basic car needs to be properly chosen and prepared according to its destination. Due to understanding problem, the paper explains differences between various kinds of four-wheeling like extreme passage rally, time race or just off-road expeditions. The paper contains classification and description of the most popular in western Europe terrain cars, their construction solutions and general advantages and disadvantages. In the document are also presented vehicle selection criteria. This issue is as significant as proper choice of adequate driving type. Established criteria relate to variety and power of engines, four wheel drive, reduction gearbox, differential locks, weight, and the most important geometric and operation parameters. Due to above features is made the comparison and choice of car for further development. The review, evaluation and selection of building elements are customized to chosen car. Project of development of interior contains construction assumptions, strength calculations and numerical model of the drawer located in the rear of the luggage. Additionally there are also drawings of arrangement of particular body elements. Graphical model, drawings and strengths calculations are performed using the Autodesk Inventor Professional 2011 and AutoCAD Mechanical 2011. Just as the chosen equipment, project is adjusted to dimensions of luggage area of chosen car. Author's design includes original spacing between the openings in exterior, what allows embedding drawer without any interference in the car body.

Keywords: *off road transport, automotive constructions, strengths calculations*

1. Introduction

Nowadays, four-wheeling becomes more popular as a kind of sport or hobby. In the area of motor sports, off-road is a significant contributor. A closer look at this comprehensive issue, allows selecting different types of off-road driving. It can be extreme passage trials, where the most important is the largest possible ground clearance, tires with high tread, very fast winches, safety cage etc. On the other hand, there are a lot of time races, where riders have to do as many laps as they can in specified unit of time. These types of rallies are identified by number of hours that crews are racing on the track (for example H1 means that whole race takes one hour). A different type of time races is competitions where crews ale obliged to pass the route as fast as possible. Some of the most famous in Europe are: Dakar Rally, Baja Championship, Drezno-Wrocław Rally. In this discipline, what counts above all is engine power and weight of the car.

A completely different kind of off-road is tourism. Tourism is the meaning of exploring foreign countries and even continents. The expedition car must be able to pass thousands kilometres without damage, meet varied climate conditions (from several degrees of frost up to dozens degrees of heat), ride over 2000 meters above sea level as well as wade in the shallow water or ride over the sand. Thus requirements for an expedition car are very wide and require few compromises. To meet these requirements, car should have simple and trouble-free solutions.

Crucial is durability and quality of components exposed to damage and the ability to quick repair away from civilization. [1]

2. Review of construction solutions

Passenger cars contain a lot of particular systems, which are responsible for different tasks. Rapid technological development and access to modern materials favours the development of newer and newer solutions. Anyway, in certain classes such as off-road vehicles, there are similarities in some construction solutions, due to simplicity of construction, reliability, strength and satisfying production costs.

2.1. Ladder frame

Frame of the vehicle has some basic and very important functions. Firstly, it is a base for other car components. It links engine and chassis elements with body. This implies a second important function that a frame transfers forces and vibrations (caused by engine and rolling wheels) to the body parts. Third function is to provide stiffness of whole construction what affect the safety. Off-road cars usually occur ladder frameworks, what means that their construction is based on two paralleled horizontal profiles. Profile's cross section can be open or closed like at the image below (Fig. 1). Longitudinal sections are connected by crossbars made of thin-walled, various shaped profiles.

Figure 1 and 2 below shows typical designs of frameworks used in terrain cars.

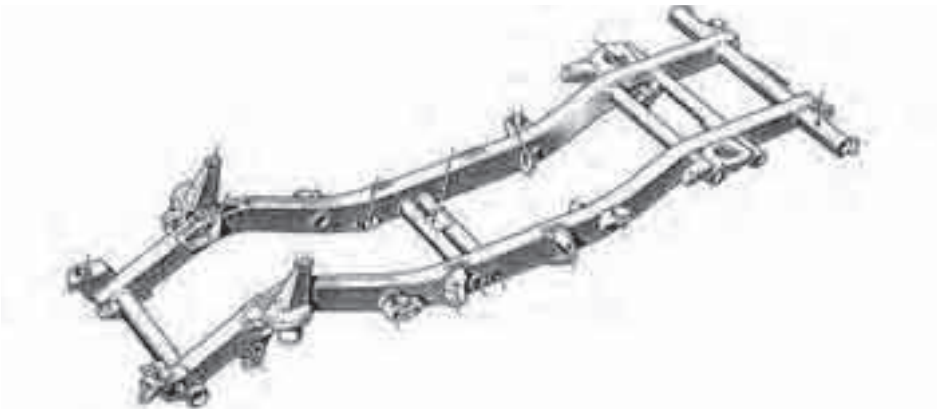

Fig. 1. Mercedes G-Class frame. [8]

Fig. 2. Typical cross sections of profiles used in frames [5]

2.2. Suspension

In contrast to independent suspension used usually in modern cars, most of good terrain vehicles have dependent suspension. This kind of solution consists of:

– rigid axle,

– trailing arms,
– springy elements (leaf springs, coil springs, rubber bushings etc.),
– shock absorbers,
– reaction rods (Panhard Rod).

Rigid axle is connected to the frame by springy elements and shock absorbers. This construction was used widely in the past, nowadays it is applied in heavy trucks, delivery trucks and terrain cars as rigid driving axle. Its disadvantage is big weight, the effect of one wheel to another, requirement of a lot of space in chassis. However, its advantage is simple and strong construction, what is required for vehicles in which there are big stresses acting on the axis [6].

2.3. Differential locks

On a turn, one rear wheel needs more speed. It has farther to travel – like the man on the outside file of a marching column of men. The other wheel needs less speed; it has to slow down on a turn – like the man on the inside of a marching column. So a unit called the differential stands between the two halves of the rear axle and takes charge of the engine speed. When your car is travelling on a straight road, the differential divides the engine speed into two equal parts – one to each rear wheel. When your car turns a corner, the differential divides the engine speed into two unequal parts. The differential takes some speed away from the wheel on the inside of the turn, and gives it to the wheel on the outside [2]. Behaviour described above is due to differential transfers more power from the engine to wheel, which has lower roller resistance. It explains difficulties of start moving on the slippery ground. This feature is undesirable in off-road conditions, where very often comes to loss traction. To avoid this situation, in terrain cars are mounted mechanisms called differential locks, which compensate differences in rotational speed of wheels. There are a few construction realizations. The most popular are:
– full mechanical locks,
– hydrokinetic locks (limited slip differential),
– electrically controlled brakes.

3. Car selection

The market offers large selection of SUVs which are identified as terrain cars. In reality, most of them are not suitable to drive off the road. Only a few car brands produce solid terrain cars. It is difficult to select the most popular vehicles for the whole Europe, due to trends and availability of some models in different parts of Europe. For example brands like Aro or UAZ are more popular in eastern Europe, while in western Europe more often can be found Mercedes or BMW. However, on the basis of literature and few years of observation and travelling through Europe, it is possible to choose some popular off-road vehicles in central Europe.
– Toyota Land Cruiser (J70),
– Mercedes G-Class (W463),
– Nissan Patrol GR,
– Land Rover Discovery I.

To select the best object for further development, cars listed above have to be analyzed. Proper set of assumptions is crucial, because it shows characteristics of vehicle. First of all, solid off-road car should have good terrain ability. Generally terrain ability is evaluated by few criteria:
– construction solutions which cause better power and torque transmission in difficult conditions,
– geometric parameters defining how chassis and body dimensions influent on ability to avoid terrain obstacles,
– operating parameters which determine mobility in extreme conditions (depth of water, maximum temperature, dust etc.) [4].

3.1. Evaluation criteria

Chosen assumptions are basic parameters that allow to select the best vehicle to travel in varied terrain.:

- Engine,
  a) variety of available engines (1-3 points),
  b) diesel engine with about 120hp (0-1 point),
- 4x4 drive,
  1 point – not occur,
  2 points – attached rear/front wheels drive,
  3 points – occur full 4x4 drive,
- Reduction gearbox (0-1 points),
- Differential locks,
  1 point – not occurs/ occur limited slip differential,
  2 points – occur incomplete differential lock,
  3 points – occur all differential locks,
- Weight of car (1-4 points),
- Angles – angle of incidence, ramp, descent, max. angle of heel, max. clearance (1-4 points).

Tab. 1. Comparison of cars

COMPARISON	Mercedes G	Toyota Land Cruiser	Nissan Patrol	Land Rover Discovery
engine a)	3	2	1	1
engine b)	1	1	1	1
4x4 drive	3	3	2	3
reduction gearbox	1	1	1	1
differential locks	3	3	2	2
weight	1	3	4	2
angles	4	1	3	2
TOTAL	**16**	14	14	12

4. Review, evaluation and selection of building elements

Preparing vehicle for long expeditions has no end. Regardless of the modifications performed in the car, as a result of regular usage, there is always list of further improvements that seem necessary, or at least useful. It is possible to create set of accessories which is acceptable minimum, however for each owner it may be a little bit different due to destination of car, individual needs, money resources and free time [3]:

- Tires,
- Springs and shocks,
- Winches,
- Bumpers,
- Roof rack,
- Side stills,
- Fuel tank protection,
- Snorkel,
- Building of the luggage,
- Ladder.

5. Project of building

The project of the drawer sliding and opening through the back door is focused on the luggage space in Mercedes G. To perform that design properly, it is necessary to determine some assumptions of further construction:

- easy installation and removal of drawer with frame. Additional assumption of fixing is an attempt to design mounting in a way to use only original openings in the back of the car, without violating the body of vehicle,
- strength and stability of the construction. This requirement refers primarily to the rails which connect drawer with frame – they must carry opened and loaded drawer,
- extension lock. This is much needed element which allow secure access to the luggage area, when a car is staying at angle causing automatic eject of the drawer,
- low weight of construction. Design should be made of lightweight materials due to don't increase weight of the vehicle too much,
- separation between passenger and luggage space. It is element of safety, which prevents moving of equipment from the luggage space to passenger area during sudden accelerations (for example: braking).

Construction elements:

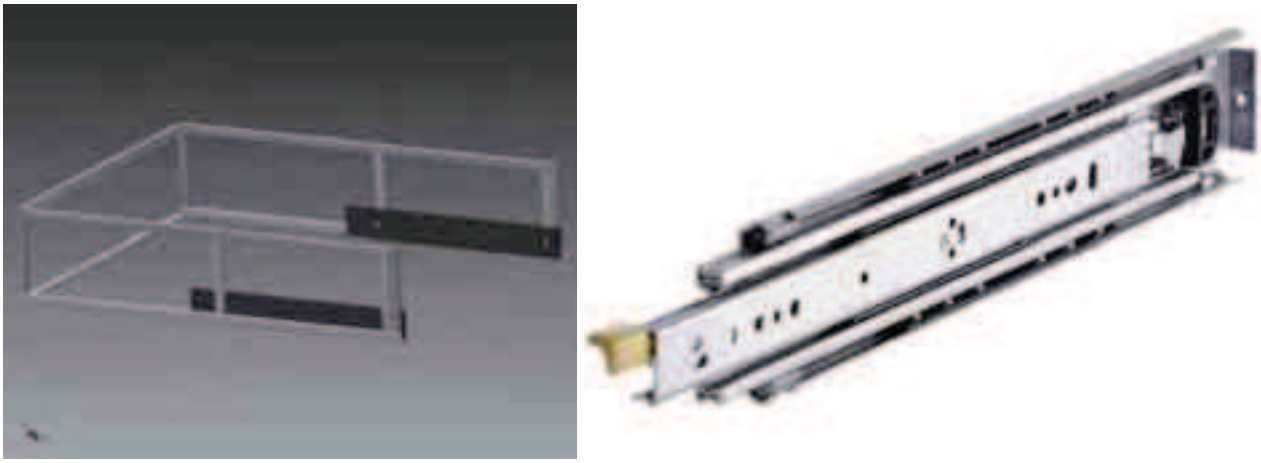

Fig. 3. Otter frame and Rails [7]

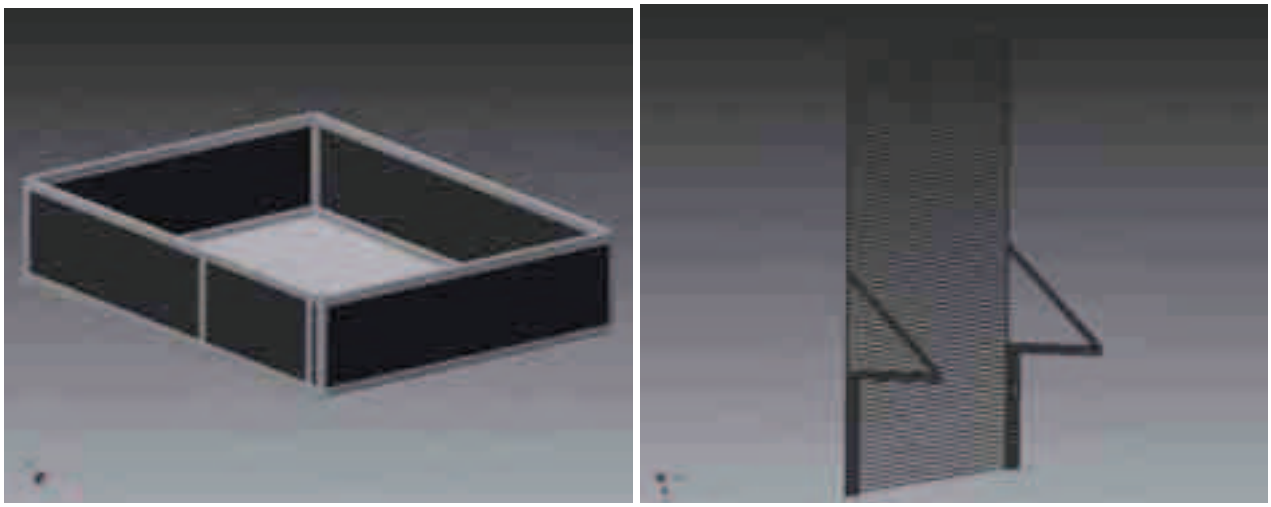

Fig. 4. Internal Frame and Barrier

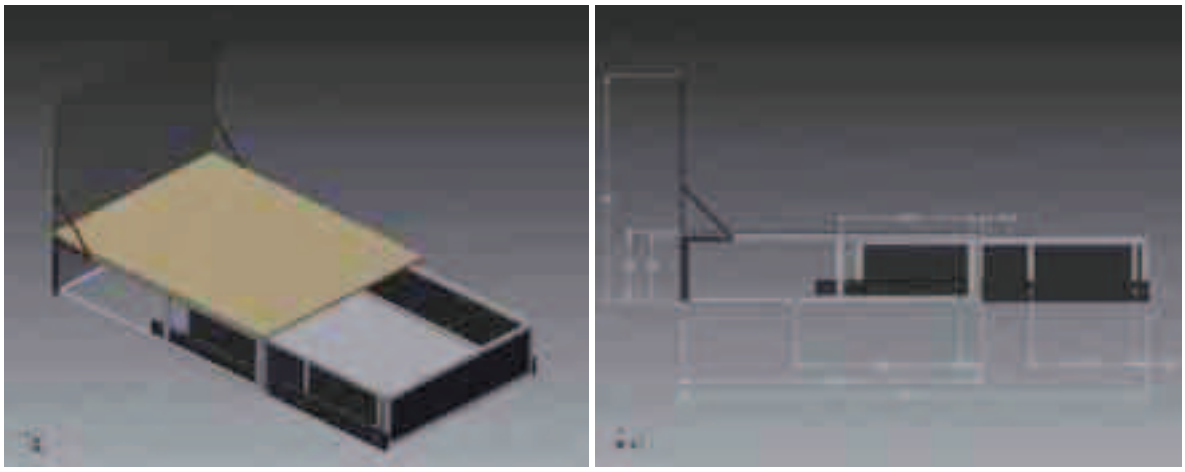

Fig. 5. Complete drawer

6. Strength calculations

Ropes, tapes, groceries, clothes or other equipment are usually carried inside the drawer. Strength calculations of the floor of the drawer have been simplified to the flat plate made of 3 mm thick steel. Floor was loaded with the force of 80 kilograms – weight of an adult. Simulation was made with using Autodesk Inventor Professional 2011, results of stress and displacement analysis are presented on Fig. 6 and Fig. 7.

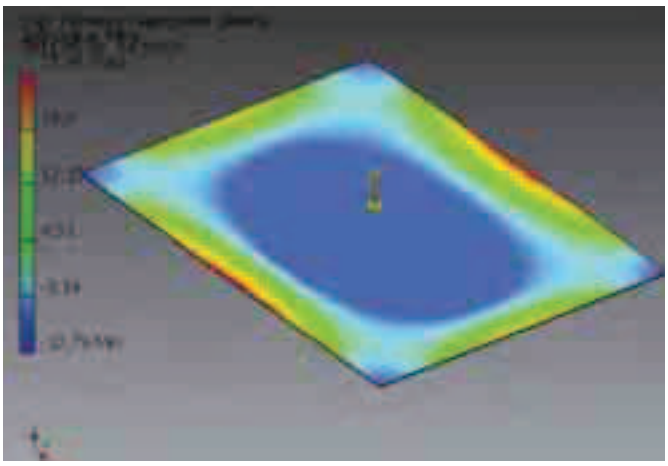

Fig. 6. Stress analysis

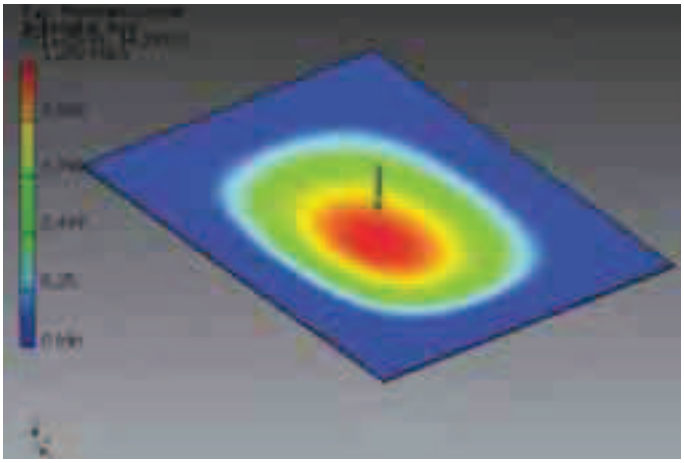

Fig. 7. Displacement analysis

Maximum stress generated in the loaded floor is 27.45 MPa. Acceptable bending stress for chosen material is about 115 MPa, what means that for 80 kg load there is no need for additional reinforcements. 1.25 mm bending shown on Fig. 7 is also satisfying result. For comparison, floor made of alluminum alloy bends three times more.

7. Conclusions

Project of development of interior was performed on the basis of Mercedes G-Class. Construction and other building elements added to serial car has changed it to an expedition car which allows to travel all over the world. Due to size of the drawer, number of crew is limited to the driver and pilot. Car selection was made in a result of comparison according to criteria combined into tables, which demonstrated in easy way main advantages and failures of each car. Fact that the winner is Mercedes, does not mean that other cars are not suitable for that kind of development. Tab. 1. shows that difference between first and second and equal third place of comparison was only two points, what means that other cars are also adequate to perform. In the paper, beside the drawer, were mentioned other building elements. All together is only needed minimum, and the market offers much more useful equipment which allows to create an ideal expedition car. However, they were deliberately skipped, because of using most of them is caused by destination, duration and speculated conditions of the expedition.

Building off-road vehicle is very complex and large subject. Despite the implementation of described construction, the issues raised in the work do not exhaust the subject. Some of them may be topics for further development (for example design additional lighting or each of listed in fourth paragraph element). The paper will facilitate the work of people who plan to adapt their cars to off-road expedition. Additionally, this document shows that issue such as off-road connected with traveling becomes increasingly popular type of spending free time, and it becomes passion of more and more people.

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