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MANUFACTURING SPECIFICITY OF VEHICLE'S INDEPENDENT SUSPENSION SYSTEM PARTS

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RESEARCH ARTICLE

ABSTRACT: Independent suspension system of a vehicle allows vertical movements of a wheel, without it affecting the other wheel of the same axle, unlike the solid one. Many elements of the independent suspension systems have been made out of steel in the past, but are recently being replaced by other new materials. Achieving top quality and short cycle times of machining, along with minimising cost per piece have always been key goals for mechanical engineers for technology. Many cutting tool manufacturers make recommendations regarding the selection of machining operations and tools for a range of automotive industry components. These recommendations are presented in this paper and should be kept in mind when designing the technology.

KEY WORDS: vehicle, independent suspension, cutting tool, machining

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SPECIFIČNOSTI PROIZVODNJE DELOVA SISTEMA NEZAVISNOG OSLANJANJA VOZILA

REZIME: Nezavisni sistem oslanjanja kod vozila omogućava nezavisno vertikalno pomeranje točkova, bez međusobnih uticaja, za razliku od zavisnog sistema oslanjanja. Mnogi elementi nezavisnih sistema oslanjanja izrađivani su od čelika u prošlosti, ali ih u poslednje vreme zamenjuju drugi novi materijali. Postizanje vrhunskog kvaliteta i kratko vreme ciklusa obrade uz minimiziranje troškova, su uvek bili ključni ciljevi inženjera - tehnologija. Mnogi proizvođači reznih alata daju preporuke za izbor postupaka obrade pojedinih delova za automobilsku industriju. Te preporuke za izradu delova sistema nezavisnog oslanjanja su prikazane u ovom radu i treba ih imati na umu prilikom projektovanja tehnologija izrade.

KLJUČNE REČI: vozilo, nezavisno oslanjanje, rezni alat, obrada rezanjem

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1. INTRODUCTION

Independent suspension system of a vehicle allows vertical movements of a wheel, without it affecting the other wheel of the same axle (Figure 1), unlike the dependent one. Most passenger vehicles and light trucks are equipped with an independent suspension system on the front axle, which provides a greater amount of engine space, greater wheel displacement, better vibration resistance, and overall better ride comfort, in comparison with the dependent system [9, 10].

The main disadvantages of this system are the complexity of the construction and the cost of production, due to the increased number of parts. Of course, the independent suspension system can be applied to the rear axle of the vehicle [18].

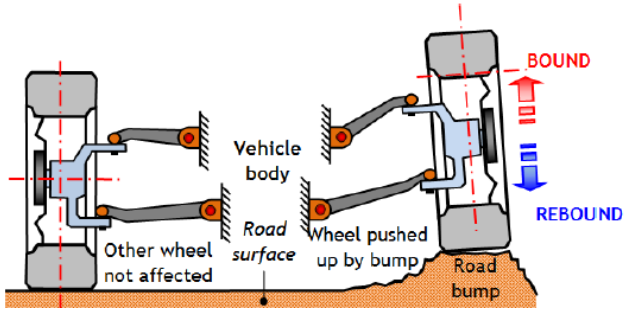

Figure 1. Independent suspension system (front view) [1]

There is a number of different types of independent suspension systems that are used:

- MacPherson suspension system
- Double wishbone suspension system
- Multi-link suspension system and
- Trailing arm.

The MacPherson suspension consists of a control arm and strut shock absorber assembly (damper and coil spring) which allow the wheel to move vertically. The main components of the system are shown in Figure 2a. It can be used on both the front and rear axle of the vehicle. Use of this suspension type results in reduced number of parts compared to other types of independent suspension, less weight and greater ride comfort. The key disadvantages include the requirement of additional space in vertical direction and lower levels of adaptability and performance.

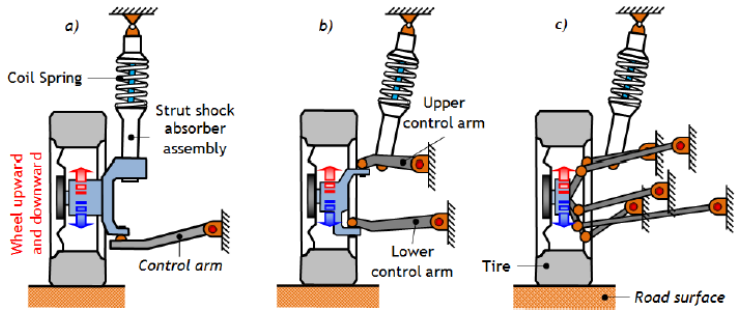

Figure 2. Different types of independent suspension system [2]

a) MacPherson suspension, b) Double wishbone suspension, c) Multi-link suspension

Double wishbone suspension system consists of two control arms, upper and lower, which are often called *a-arms* or *wishbones*, due to their shapes. It is mostly implemented in luxury and sport vehicles, as it provides a favourable compromise between vehicle handling and comfort. It consists of two control arms that prevent tilting of the wheels (Figure 2b). The control arms usually are of different lengths, with the lower one being longer.

The leading advantage of this type of suspension is an increase of negative camber, which is a direct consequence of vertical movements of the upper and lower arms. This has a positive effect on the stability of the vehicle, as the outer wheels maintain better contact with the surface during cornering. The disadvantage compared to other solutions is the complexity of the construction, the cost of production, the increased number of parts such as joints and bearings, which increase wear of tires. Multi-link suspension system possesses three or more lateral and one or more longitudinal control arms, which have different lengths (Figure 2c). This system offers a good compromise between comfort, stability and handling. The advantage is that certain parameters of this system can be adjusted without affecting the entire assembly. However, this system is more complex and expensive than others. When it comes to off-road vehicle applications, the disadvantage is that it does not provide sufficient vertical wheel movement.

Figure 3 presents the double wishbone suspension system produced by ZF.

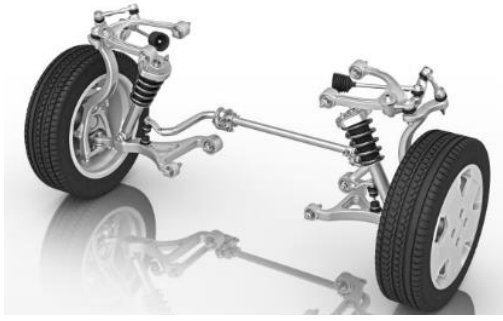

Figure 3. ZF double wishbone suspension [3]

Figure 4 gives an example of an independent suspension as a major component of a driveline system for high-mobility vehicles, suitable for fast light-duty vehicles and heavy

Armoured Personnel Carrier (APC) or Mine Resistant Ambush Protected vehicles (MRAP) [12].

Figure 4. Independent suspension axles for high mobility vehicle [12]

2. INDEPENDENT SUSPENSION COMPONENTS MANUFACTURING

2.1 Forming of independent suspension components

Before observing forming and machining processes for independent suspension components, it is necessary to select materials which will be used. During the selection of the materials, it is crucial to take into account that the selected materials must allow smooth driving on different terrains, during high accelerations, sudden braking and other more extreme situations. Very important factor is also the lifetime of elements, which should range from 107 to 108 driving cycles versus a defined stress loading and stiffness criteria.

Many elements of the independent suspension systems have been made out of steel in the past, but are recently being replaced by other materials, such as compacted graphite cast iron (CGI), spheroidal graphite iron (SGI), and magnesium/aluminium alloys, which significantly contribute to weight loss [4]. Examples of different independent suspension constructions are shown in Figure 5 [11].

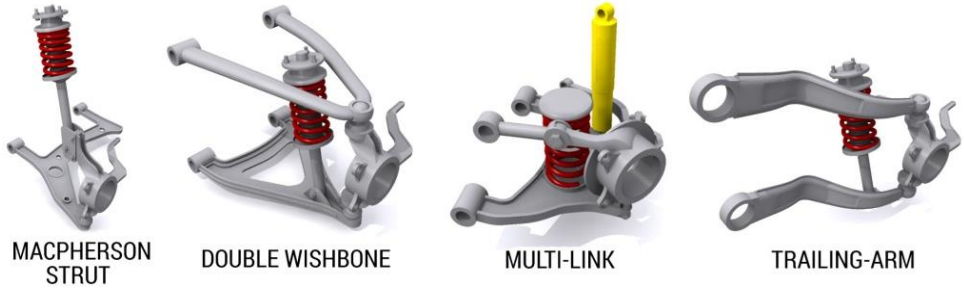

Figure 5. Examples of different independent suspension constructions [11]

Depending on the selected material, thickness of the element and the available accommodation space, it is decided whether the element will be forged or casted. Forged control arm can be seen in Figures 6 and 7.

The steering wheel is that component of the vehicle that connects the suspension system, the braking system and the steering system to the vehicle chassis, which is why the design and

production of the steering system wheel cannot be separated from the design and manufacture suspension system.

Figure 6. Forged control arm [5, 13]

Figure 7. Forged Auto Parts Control Arm for Trailers [14, 15]

Production of a steering knuckle (Figure 8) can be used in order to present some of the forming technologies, as well as machining processes. The first step in knuckle production is casting. It is important to select the type of casting technology, e.g. gravity, low pressure, high pressure, semi-solid, squeeze casting, etc. The quality and profitability of casting process depend on the metallurgical properties of the metal, mold design, process productivity, repeatability of the production conditions and properties of the part after heat treatment [6].

Figure 8. Casted and forged steering knuckle [7, 16, 17]

2.2 Machining of independent suspension elements

Depending on the material that will be machined, characteristics including rigidity, spindle and attachment size, power and torque, and spindle velocity will be very important to define the most appropriate machine tool. Linear or rotating transfer machines or twin spindle machining centres are still preferred for high production volume, while machining centres (single or twin spindles) are preferred for lower production batches or mixed production batches. Achieving top quality and short cycle times of machining, along with minimising cost per piece have always been key goals for mechanical engineers for technology. The steering knuckle is usually produced in one or two set ups on machining centres [8].

Surfaces, parts and machining operations for typical front steering knuckles and typical rear knuckle are describes in Figure 9 [20]. Due to a limited number of position available in the tool magazine and the desire for short cycle times, the presented tools are be adapted to machining multiple operations. Due to a large variety of component concepts and shapes, the following pages describe most of the features concerning machining of a steering knuckle.

Figure 9. Surfaces operation machining [20]

1. Strut mount
2. ABS/ABR sensor location
3. Steering arm, tie rod location
4. lower ball joint location
5. Ball bearing location outer diameter machining
6. ball bearing location
7. Brake caliper fastening holes
8. wheel spindle

After the casting process, the portion of the knuckle which is used for connecting it to the damper and upper control arm is subjected to double side milling (Figure 10), using an indexable side cutter.

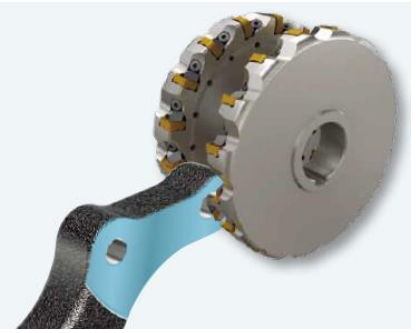

Figure 10. Double side milling [8]

This is followed by drilling a hole (Figure 11) for making a connection with the brake caliper.

Figure 11. Drilling [8]

Full side face milling of the lower control arms and tie rods is also necessary, as shown in Figure 12.

Figure 12. Full side face milling [8]

Drilling and chamfering of the edges of the joint used for connecting the steering knuckle with the lower control arm (Figure 13a) is the next step, followed by hole drilling for ABS/ABR sensor location (Figure 13b).

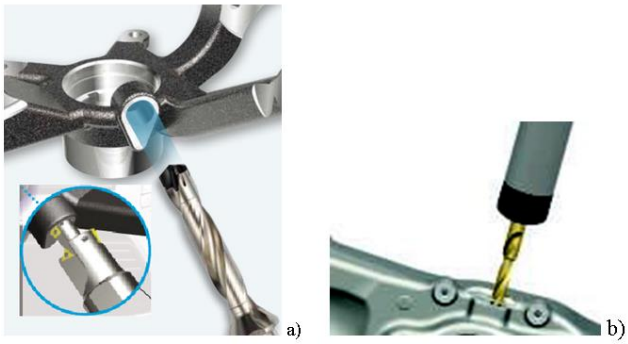

Figure 13. Drilling [8]

High precision boring (Figure 14) of the knuckle centre hole represents the next step.

Figure 14. High precision boring and sample tool for boring [8]

Following this, slotting is performed (Figure 15).

Figure 15. Slotting [8]

Figure 16 illustrates the final step, which includes face roughing and finishing.

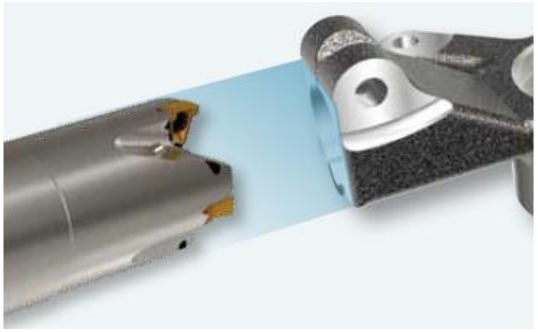

Figure 16. Face roughing and finishing [8]

In the Figure 17 machining wheel spindle with special cutting tools is shown. Special tools are used for outside turning, chamfering, radius forming and longitudinal turning & chamfering.

Figure 17. Machining wheel spindle [20]

3. CONCLUSIONS

There is a number of forming processes that are needed in order to produce intermediate forms of suspension components, and those are mainly forging and casting. After producing work pieces, machining of the same is performed. Machining processes that are used are drilling, milling, slotting, boring, as well as roughing and finishing of component's faces. It can be said that the same technologies are applied in case of independent and dependent suspension components. The leading dissimilarity is that independent suspension system integrates a much greater number of components, which are simultaneously more complex than dependent suspension components. This leads to a greater cost of production than in the case of dependent suspension. Be that as it may, cost is not the only factor which affects selection of the suspension type. Dependent suspension is more robust and provides better performance in case of extreme off-road applications, but the independent one contributes to

a greater vehicle ground clearance, reduction of mass, better fuel economy, as well as handling and ride comfort, so all of these factors have to be taken into account Many cutting tool manufacturers make recommendations for the choice of machining operations and tools. These recommendations are contained in this paper and should be kept in mind when designing the technology.

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