EVALUATION OF HEAT TREATMENT METHODS USED FOR THE PRODUCTION OF TRANSMISSION COMPONENTS

BRADÁČ Josef, FOLTA Martin

ŠKODA AUTO University, Mlada Boleslav, Czech Republic, EU
josef.bradac@savs.cz, martin.folta@savs.cz,

Abstract

At the present time, the heat treatment process plays an important role in the production of automobile parts. This is valid especially for the transmission components. During the last few years, it has been possible to see increasing requirements for these components. The main aim of the heat treatment, in case of the transmissions components, is to improve the desired properties of the final product. This is primarily to increase the hardness and resistance of wearing such components and thus to prolong their lifetime. This paper compares two methods of heat treatment. The first method is oil hardening and the second hardening in gas pressure. The production quality, process timing, required temperature and operational costs are set up as basic evaluation criteria. On the basis of this analysis, the suitable method for mass production of gearbox components is recommended.

Keywords: Heat treatment, transmission components, production quality

1. INTRODUCTION

The term automotive components is possible to understand as all the parts that make up the car, from the smallest parts, such as screws, nuts and pads to larger parts such as the engine block, axles and the car body parts. Most of the components are first assembled into units and then mounted to cars. Not all parts are manufactured by the producer; some are delivered already pre-prepared for installation from suppliers. In contrast, parts such as engines, transmissions and axles are usually manufactured by the automakers. Most of these manufactured components are processed by refining processes. For each part there are stated different demands according to the required properties of the final product. The challenge is to produce such a part, which will be delivered at the required time, in the best quality and at an affordable price. The heat treatment is among the most important operations of processing the components. Usually it is a cementing and hardening process. The main task of cementing is to enrich the surface of a part by carbon [1]. After cementation the steel is processed by hardening and tempering. It is the most important method of heat treatment which aims to achieve a different state from the equilibrium state of steel. The main objective is to increase the hardness of the surface layer, and its wear resistance [2]. An important aspect in the hardening process is the selection of the hardening medium. Water or oil is used in the case of common heat treatment methods. The vacuum heat treatment by contrast uses the following gases: argon, hydrogen, helium, and nitrogen [3]. The aim of this paper is to evaluate and compare two methods of the heat treatment and show the main benefits of using modern technology for the production of transmission components.

2. TRANSMISSION COMPONENTS

The transmission in the car is used for transferring or disruption in torque delivery to the wheels. This all takes place by the help of transfers which allow the stepped or continuous change in gears. Inside the gearbox there are two shafts which are mounted in cylindrical bearings. Gears enabling the forward motion are provided by synchronizing elements and are situated on the output shaft [4]. In case of reverse gears there is combination of the direct and conical teeth. The gearbox is formed by not only the box but also by the final gear and the

differential, see **Figure 1**. The selected components of the gearbox, which are processed by the heat treatment, are shown in **Figure 2**.

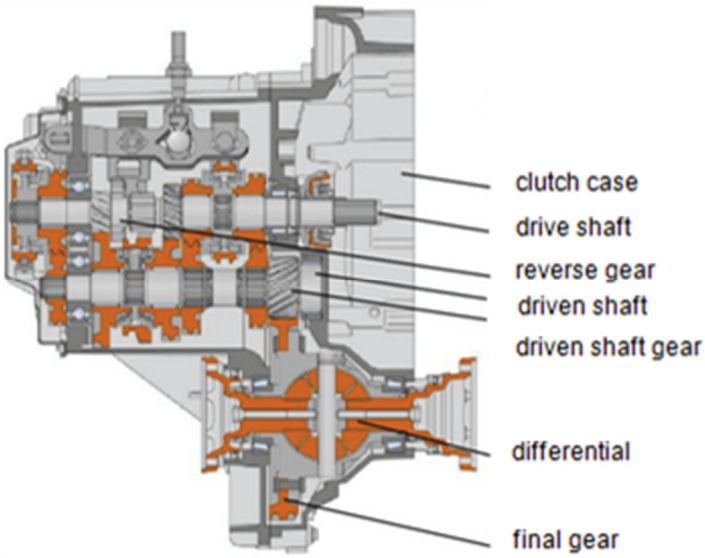

Figure 1 Schematic view of the transmission MQ 200 [5]

Figure 2 Transmission components processed by heat treatment [5]

3. HEAT TREATMENT OF TRANSMISSION COMPONENTS

The main requirements for gear components are the high wear resistance and high strength. These properties can be obtained through the heat treatment process. At the present time, the most important and most widely used method is atmospheric or vacuum carburizing followed by hardening in oil or in gas pressure. Both procedures lead to increased strength and hardness of the processed parts.

3.1. Atmospheric cementation and oil hardening

In the case of using this method, the components are refined in batch furnaces. These furnaces are divided into a carburizing and a hardening part, see **Figure 3**. At the beginning, the components are transported by help of conveyor to the furnace. The cementation process takes place in a gaseous protective atmosphere. In the second phase of this process, the components are hardened and subsequently purified, then tempered at low temperature and cooled.

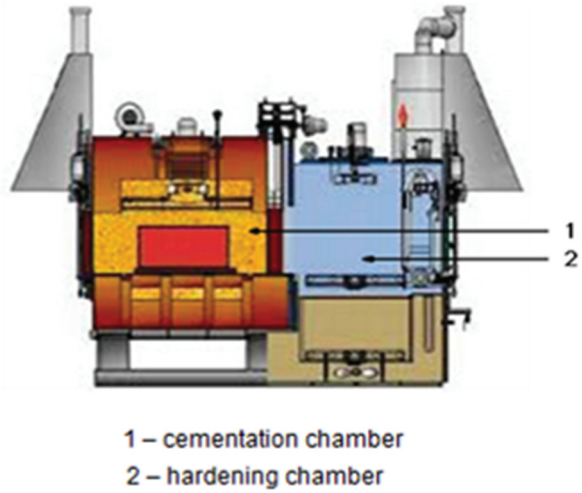

Figure 3 Furnace for air cementation and oil hardening [6]

3.2. Vacuum cementation and hardening in gas pressure

It is a modern and the most advanced method. This method is used by many car manufacturers such as VW, BMW, GM, Fiat and SKODA, while SKODA was the first company using this technology in VW Group. All these car producers use a multi-chamber furnace system, which consists of a line with the transport module comprising the hardening chamber. The transported equipment moves between cementation chambers, as it is shown in **Figure 4**. The usage of more cementation chambers enables to set each individual chamber and thereby adjust the cementation conditions for a specific part. The cementation process proceeds in the form of pulses. The number of pulses influences the depth of the carburizing layer. The whole process is fully automated, resulting in the reduction of service personnel.

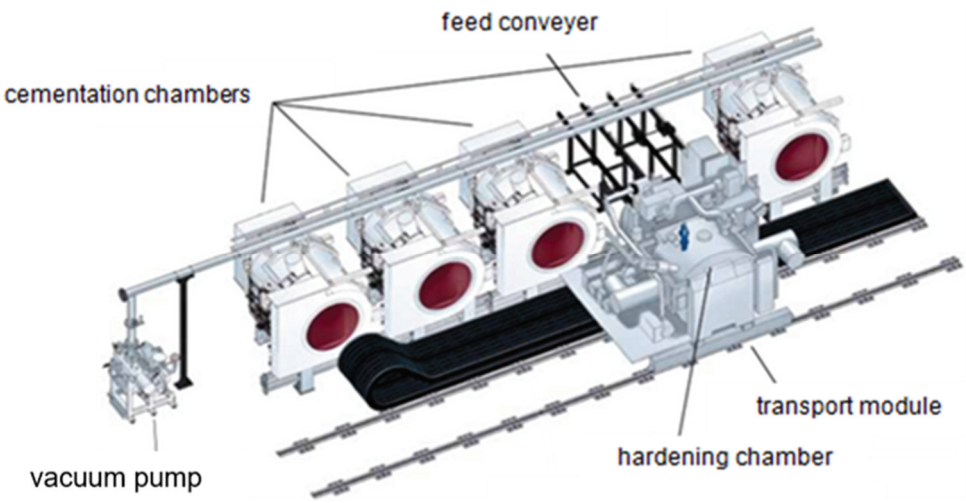

Figure 4 Vacuum cementation with hardening in gas pressure [6]

4. EVALUATION OF HEAT TREATMENT METHODS

The evaluation of the selected heat treatment methods was based on pre-defined criteria, which include all the important aspects associated with the production of such components. These were mainly the technological, economic, quality and environmental aspects. The first monitored criterion was time process, which shows the efficiency of the device in mass production. **Table 1** shows the time sequence of operations for both methods of heat treatment. It is obvious that the process of hardening in gas pressure contains a lower number of

working operations and generally shorter times, see **Figure 5**. The resulting time in case of oil hardening method is almost doubled when the large proportion of time falls on manipulation. From the comparison, it is clear that usage in the case of hardening in gas pressure is possible to produce a higher number of parts and thus achieve higher production efficiency.

Table 1 Time process of individual operations

Time duration [s]	**Oil hardening**	**Hardening in gas pressure**
Washing	0	600
Preheating	0	3600
Flush nitrogen	900	0
Cementation	16800	9000
Heating to hardening temperature	2700	0
Hardening	1800	600
Dripping	900	0
Washing	1800	0
Tempering	7200	7200
Cooling	1800	2400
Manipulation during process	9900	1800
Total number of operations	9	7
Total time [s]	**43800**	**25200**

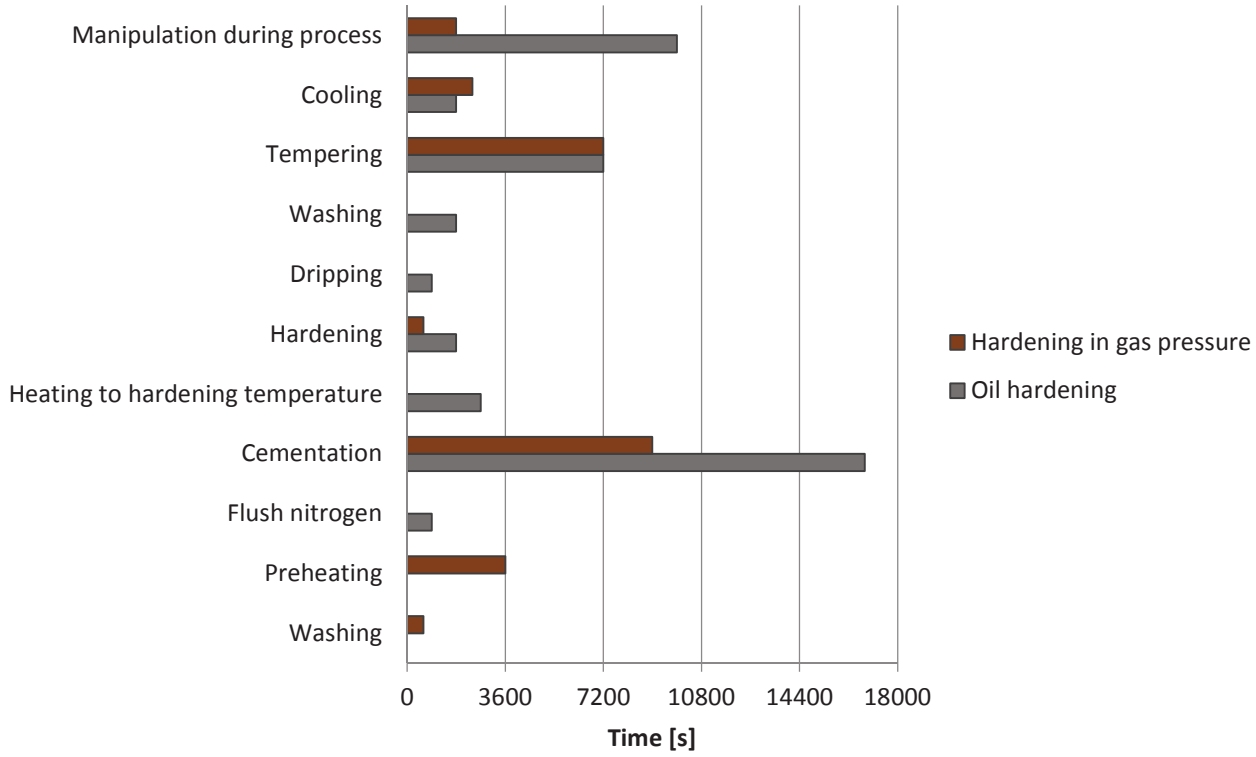

Figure 5 The bar chart of process timing analysis

Another aspect was the economical point of view that was expressed using a number of criteria relating to operational costs. A comparison of the main operating costs of both technologies is shown in **Table 2**. For simplification, it is mentioned only a relative comparison without the specific values which could not be published. It is obvious that the oil hardening method shows a higher cost of consumables, handling, personnel, and also on finishing and disposal of harmful substances. For example, the costs of hardening media and manipulation in the case of oil quenching methods are almost doubled. The method of hardening in gas pressure has only higher energy consumption and higher maintenance costs. It is mainly due to the higher temperature of the process in comparison to the oil hardening method. These costs are balanced with the higher production of parts in comparison with oil hardening.

Table 2 Economic aspects

Economic aspects	**Oil hardening**	**Hardening in gas pressure**
Hardening media costs	Higher value	Lower value
Service costs	Lower value	Higher value
Power costs	Lower value	Higher value
Manipulation costs	Higher value	Lower value
Personnel costs	Higher value	Lower value
Finishing costs	Higher value	Lower value
Waste disposal costs	Higher value	Lower value

The last assessed area is focused on the quality of the manufactured parts and environmental aspects. All the evaluated aspects are shown in **Table 3**. The evaluative rating is also used in this case due to the data secrecy. The table shows that a higher quality of parts is possible to be achieved by hardening in gas pressure. This method generally shows the lower resulting distortion of parts and a lower value of residual internal stresses. There is also no surface oxidation or backing of oil during tempering which must be subsequently removed by means of sandblasting. This also results in a smaller number of different products which is related to computer process monitoring. Hardening in gas pressure shows better environmental aspects which are currently becoming more and more important. There is no danger of vaporization of oils and the subsequent ecological disposal is not needed. The level of noise is also significantly lower, and contributes to a lower work load, thereby improving the working environment.

Table 3 Quality and environmental aspects

Quality aspects	**Oil hardening**	**Hardening in gas pressure**
Risk of oil backing	YES	NO
Risk of oxidation	YES	NO
Deformations	Higher level	Lower level
Internal stresses	Higher level	Lower level
Necessity of sanding	YES	NO
Number of scraps	Higher level	Lower level
Computer process monitoring	NO	YES
Environmental aspects		
Noisiness	Higher level	Lower level
Oil evaporation	YES	NO
Oil disposal	YES	NO
CO_2 production	Higher level	Lower level

5. CONCLUSION

The production of transmission components is an important part of the whole manufacturing process of the passenger car. All of these components must meet very strict specific quality requirements and must ensure the functionality of the mechanism not only at the end of the production line, but also throughout the lifetime of the automobile. This results in high demands on resistance of these parts which correspond to the working load. The required properties can be achieved through the heat treatment of these components. When choosing a method of heat treatment it is necessary to take into account not only the technological and qualitative aspect but the economical ones as well. Another aspect which is more and more important nowadays is the view of ecology, mainly the production of harmful substances and waste.

In relation to the above mentioned aspects, two methods of heat treatment, which are used for the production of transmissions components, were introduced in the paper. The analysis showed that the method of hardening in gas pressure is better from all the points of view. It makes more efficient use of the operating equipment, has lower operating costs and is better for the environment while helping to improve working conditions in compliance with all the technical requirements for the quality of the manufactured parts. On the other hand, it must be said that the purchase costs of production equipment for this method are higher. In the mass production of components it is nevertheless, more beneficial in terms of more efficient utilization of the production equipment and fulfilment of strict technical requirements for the quality of the manufactured components. This is the base element for the successful and cost-effective manufacturing process and above all satisfied customers.

REFERENCES

[1] CHOTEBORSKY, R. Material Science. 1st ed. Prague: CULS, 2006. 134 p

[2] PTACEK, L. Materialogy II. 1st ed. Brno: CERM, 2002. 392 p

[3] HEERING, D. H. Vacuum heat treatment. 1st ed. Deerfield: BNP Media II., 2012. 536 p

[4] VLK, F. Vehicle transmission. 1st ed. Brno: FV Publishing, 2006. 371 p

[5] Skoda Auto, Inc. Transmission components of MQ200. 2015

[6] Aichelin and ALD furnace promotion materials, 2015