PRENITLPC® – THE MODERN TECHNOLOGY FOR AUTOMOTIVE

Kula Piotr[1], Pietrasik Robert[1], Dybowski Konrad[1], Korecki Maciej[2], Olejnik Józef[2]

[1] Technical University of Lodz, Institute of Materials Science and Engineering, 90-924 Lodz, Stefanowskiego 1/15, Poland,
[2] SECO/WARWICK S.A., 66-200 Swiebodzin, Sobieskiego 8, Poland

Abstract

Low pressure carburizing technology has been more commonly used nowadays for automotive industry, successfully replacing the traditional technologies. There is a great interest to broaden the applications of this technology and to optimize the low pressure technologies. The most promising approach concerns the addition of nitrogen together with carbon into the surface layer. This leads to the improvement of the layers' functional properties and economic effects.

The influence of ammonia addition at the heating stage on the layers formation during low pressure carburizing is discussed. The advantageous effect of PreNitLPC® technology on fatigue strength and pitting is proved. Economic aspects of this technology are also demonstrated in comparison to carburizing, i.e. concerning the significant shortening of the process time.

Key words: low pressure carburizing, vacuum carburizing, prenitriding, LPC, PreNitLPC®, thermo chemical treatment, surface treatment.

1. Introduction

Carbonitriding, which is the alternative process for carburizing and nitriding, is one of the most common thermo-chemical processes used in industry. Generally it improves the mechanical properties of surface layer of mechanical elements. During that process both carbon and nitrogen atoms diffuse, up to the saturation state, into the surface layer of mechanical elements. This technology was invented in the mid sixties of last century in order to enhance mechanical properties in comparison to properties of elements obtained after carburizing. The surface hardness and abrasive wear increased after carbonitriding. The fatigue strength of steal parts was also improved.

The most efficient method of surface layer saturation with carbon and nitrogen is bath cyaniding in melted salts. However, due to the high toxicity of this method it was eliminated from industry. O the other hand the gaseous carbonitriding was not efficient enough to successfully replace the bath cyaniding.

The necessity of intensification of the surface layer carbon saturation processes resulted in the significant development of low pressure thermo-chemical treatment. This technology has become very competitive due to its shorter time of treatment and repeatability, regardless the high costs of equipment. Additional aspect of low pressure treatment is the fact that it is more environmentally friendly process in comparison to conventional technologies.

Low pressure carburizing technology FineCarb®, which was elaborated in Institute of Materials & Engineering Science at Technical University of Lodz with the Seco/Warwick S.A. collaboration, allows to get the carburized layers within shorter time than gaseous one. The process is fully controlled and repeatable. Due to the gas quenching (nitrogen, helium and hydrogen) it is environmentally friendly.

Nitrogen supported carburizing PreNitLPC® allows the expansion of the applications of FineCarb® technology toward higher carburizing temperatures and wider range of steel grades. This technology has been elaborated in Institute of Material Science & Engineering and is ready for industrial applications.

Technically, it is based on the dosing of the ammonia gas to the vacuum furnace chamber during continuous heating of charge at the temperature interval from 400°C to the moment, the charge reaches the carburizing temperature. As a result, carburized layers at higher temperatures do not demonstrate the grain growth. Due to the higher temperature of the process (even 1000°C) it can be run for a shorter time without any negative impacts on the microstructure and mechanical properties. PreNitLPC® is modern, economic alternative of low pressure carburizing, which allows to intensify this process.

2. Experimental

Series of low pressure carburizing – LPC and low pressure carburizing with prenitriding option - PreNitLPC® processes were done at different temperatures in order to compare the structure and properties of created layers.

Two types of steel were carburized, 16MnCr5 and 17CrNi6-6. Acetylene-ethylene-hydrogen atmosphere was applied, nitrogen was obtained from ammonia dissociation in a case of prenitriding option. Carburizing atmosphere and ammonia were dosed according to procedures described in the patent [4] and patent [5], respectively. Ammonia was added at the temperature range 400°C ÷ 700°C at the heating stage of the charge. Additionally, the conventional process was done in order to compare those methods. The process parameters are shown in Table 1.

Table 1. Carburizing process conditions.

Type of carburizing	Conventional	LPC	PreNit LPC		
Process temperature	920°C	920°C	950°C	980°C	1000°C
Thickness layer (criterion 0.4%C)	0.6mm				
	2.0mm	-			2.0mm
Surface concentration	0.8 %C				

3. Results

3.1 Shortening of carburizing time

Carburizing at higher temperature decreased the process time. This was due to the much higher carbon diffusion coefficient at higher temperatures (exponential dependence). The processes time for different conditions are demonstrated in the Table 2 and Figure 1.

Table 2. Processes time obtained for different carburizing conditions.

Type of carburizing	Conventional	LPC	PreNi LPC		
Temperature	920°C	920°C	950°C	980°C	1000°C
Thickness layer (criterion 0.4%C)	0.6 mm				
Boost time	167min	23min	17min	13min	11min
Diffusion time	-	1h 52min	1h 24min	58min	43min
Total process time	2h 47min	2h 15min	1h 41min	1h 11min	**54 min**

As one can see, the shortest total time of process was obtained for the carburizing with prenitriding at the highest temperature 1000°C. The created thickness layer was 0.6 mm only after 54 min of treatment. Such a short time is 68% lower in comparison to conventional carburizing and 60% lower when compared to LPC, when done at 920°C (Figure 1). This was very promising from economic point of view, provided that the mechanical properties of obtained layers at 1000°C were at least the same as those at 920°C. Further research of microstructure and properties of those layers was done in order to verify this option.

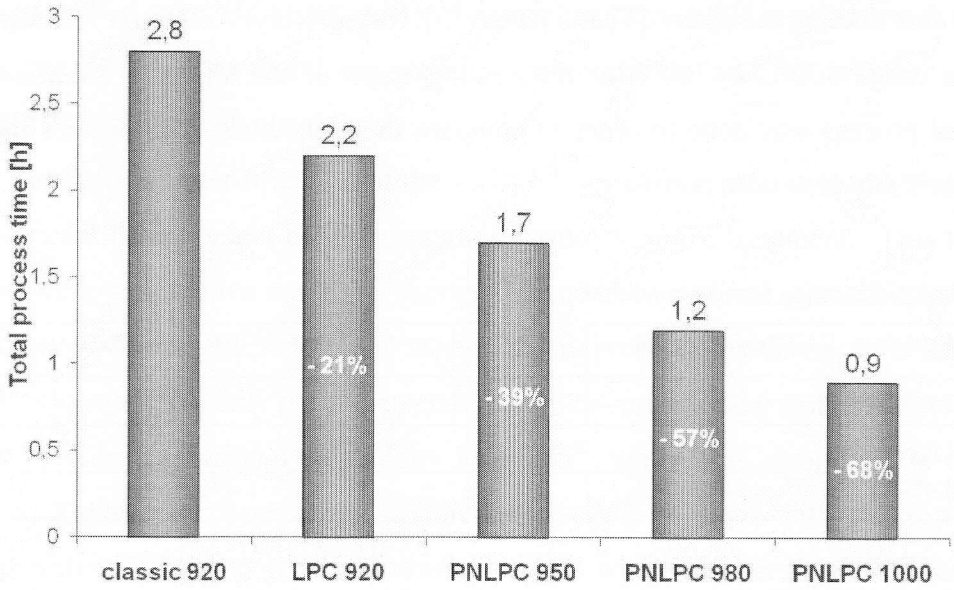

Fig. 1. The comparison of total processes time for different types of treatment

3.2 Microstructure

The structure of created layers at different carburizing processes and grain size of previous austenite were established. The results are shown in Figure 2. One can see the grain size was significantly lower when PreNitLPC® was used. Additionally, the size was smaller even when temperature of the process was 1000°C, when compared to the carburizing at 920°C without prenitriding option.

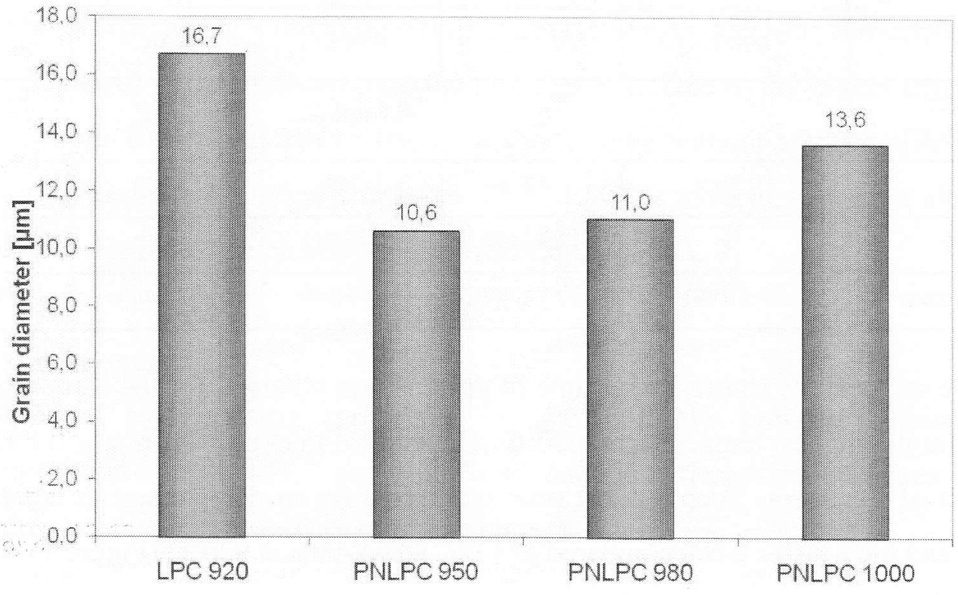

Fig. 2. The comparison of the surface layer grain size for 16MnCr5 steel for different types of treatment

The influence of the temperature on the grain size of the core was also established. As it was expected, the grain diameter of the core was higher at the process temperature PreNitLPC® 1000°C than at LPC 920°C, and was equal 19.2 μm and 12.2 μm, respectively for the 16MnCr5 steel. This was the result of the nitrogen presence only in the surface layer, which was added at the heating stage.

To sum up, the prenitriding option allows to shorten the total process time when the temperature is higher, while the grain growth in the surface layer is eliminated.

3.3 Strength properties

It was crucial to determine the mechanical properties of obtained layers in order to establish the potential of applications of the PreNitLPC® technology in comparison to other carburizing methods.

It appeared that hardness penetration pattern in the surface layer of 16MnCr5 steel was comparable to the results for LPC technology, when the technology PreNitLPC® at higher temperature was applied.

The fatigue strength for bending was measured. The calculated Wöhler's curves within limited and unlimited range of fatigue strength for processes LPC 920°C and PreNitLPC® 1000°C are shown in Figure 3. It appeared that the fatigue strength for bending was higher after PreNitLPC® for 17CrNi6-6 steel.

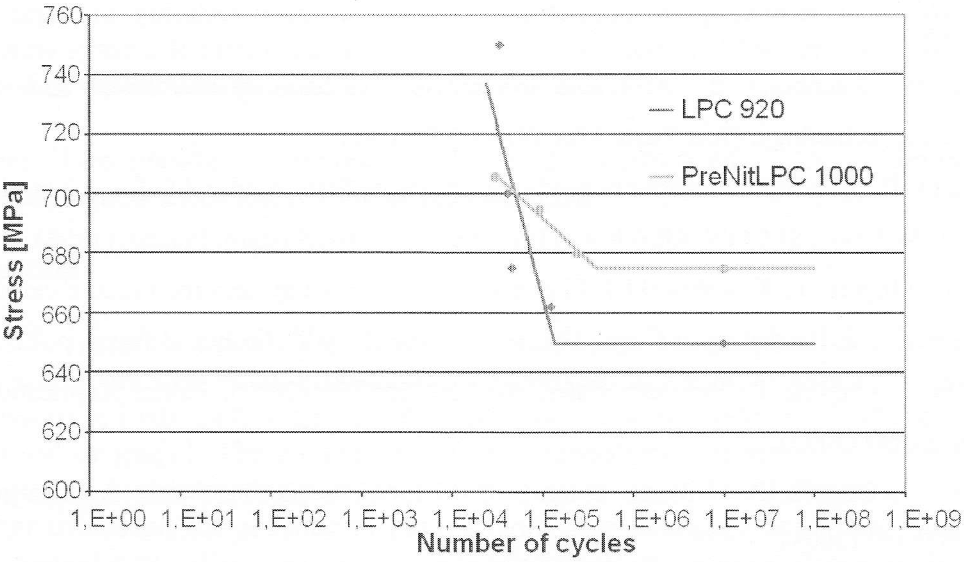

Fig. 3. Wöhler's curves within limited and unlimited range of fatigue strength for different types of treatment, 17CrNi6-6 steel

The fatigue strength for pitting was also determined. No matter what the carburizing method was used, the results were comparable in the case of 16MnCr5 steel and were equal 1,6 x 10^{+6} cycles.

4. Summary

The described results demonstrated that surface layer properties obtained by using the PreNitLPC® technology were comparable to LPC in a case of pitting and hardness. The nitrogen addition at the heating stage caused the increase of fatigue strength for bending. Higher temperature of PreNitLPC® technology (1000°C) resulted in smaller grain size in comparison to LPC920°C.

In conclusion, it was shown the PreNitLPC® technology can be done at significantly higher temperatures than LPC and conventional technologies, without the lost of good mechanical properties. It is possible to shorten the total process time for the required thickness layers when the temperature increases. That is very beneficial from economic point of view. Therefore, PreNitLPC® technology can be an excellent tool for applications in serial automotive industry.

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