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Heat treatment of cold formed steel forgings for the automotive industry

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Manufacturing and processing

ABSTRACT

Purpose: In the Slovenian company ISKRA Avtoelektrika they manufacture, with the processes of cold forming, a great number of a different steel forgings for the Slovenian and European automotive industry. During their exploitation they are exposed to the high mechanical and temperature loads.
Design/methodology/approach: A gas furnaces and devices play important role in the heat treatments of various metal parts for the automotive industry. Their thermotechnical characteristics have a great influence on the product quality and costs. The basic aim of our investigation work is to present the optimization of a device with emphasis on continuous control of working temperature.
Findings: The efficiency and quality of the treatment were analysed with the use of: chemical analysis, hardness measurements, measurements of carbon and sulphur content in the surface layer, and metallographic examination methods.
Research limitations/implications: For economical production of cold formed steel forgings for the automotive industry it is important that they have a long working life. The corresponding mechanical and thermal properties of the steel forgings are achieved by a heat treatment.
Practical implications: As a practical example is presented an optimisation of the heat treatment procedure for typical cold formed steel forging for the automotive industry from the ISKRA Avtoelektrika production program. The practical result of the used heat treatment are the cold formed steel pinions with the surface hardness of approximately 65 HRC, and the case hardened depth of the surface layer approximately 0.7 mm.
Originality/value: On the basis of the results of our technical investigation work and corresponding economical studies, the second device (of the same producer, type and capacity) for the heat treatment was installed at the end of last year.
Keywords: Heat treatment; Steel forgings; Temperature measurements

1. Introduction

In the Slovenian company ISKRA Avtoelektrika they manufacture, with the processes of cold forming, a great number of a different steel forgings (Figure 1) for Slovenian and European automotive industry.

The cold formed steel forgings [1] are, during their exploitation, exposed to the both: high mechanical and temperature loads [2,3].

In the frame of our investigation work, the efficiency and quality of the heat treatment (case hardening) [4-8] of the most typical cold formed steel forging from ISKRA Avtoelektrika production program – pinion no. 16.920.633 has been analysed. The material of the pinion is 16MnCr5 grade steel (Table 1), produced in Slovenian steelwork Metal Ravne, with well known mechanical and thermal properties [9].

Table 1.
Chemical composition of 16MnCr steel

		(Mass. %)								
	Element	C	Si	Mn	Cr	Cu	Al	Ni	P	S
Testing	Analysis 1	0.162	0.241	1.192	1.014	0.049	0.033	0.147	0.013	0.026
Charge	Analysis 2	0.164	0.247	1.167	1.028	0.044	0.035	0.146	0.014	0.027
Standard [9]		0.14-0.19	<0.40	1.00-1.30	0.80-1.10				<0.035	<0.035

Fig. 1. Cold formed steel forgings from ISKRA Avtoelektrika production program. Testing forging – pinion no. 16.920.633 (below, the second from the left)

A device for heat treatment installed in ISKRA Avtoelektrika (Figure 2) is produced by the company CODERE from Switzerland. It consists of a four main parts:

- gas furnace (with pure and high controlled atmosphere),
- primary temperature measuring system (measuring the atmosphere temperature in the furnace),
- manupulating system, and
- hardening vessel (with mineral oil) [10].

Fig. 2. Device for heat treatment in ISKRA Avtoelektrika

2. Experimental work

2.1. Temperature measurements

For the purpose of temperature measurements [11] of the testing charge we designed a secondary temperature measuring system (Figure 2) consisting from three basic elements [12]:

- even coated Ni-NiCr thermocouples,
- data acquisation modul ADAM – 4018 [13], and
- PC computer which recorded the results of the measurements.

In the frame of our investigation work five testing forgings were bored. Ends (tips) of thermocouples were inserted therein and fixed with wire. Then, in the filling of the basket with the forgings, the five testing forgings were put on precisely defined, pre-selected places in the basket (A, B, C, D and E). Their positions are shown in Figure 3.

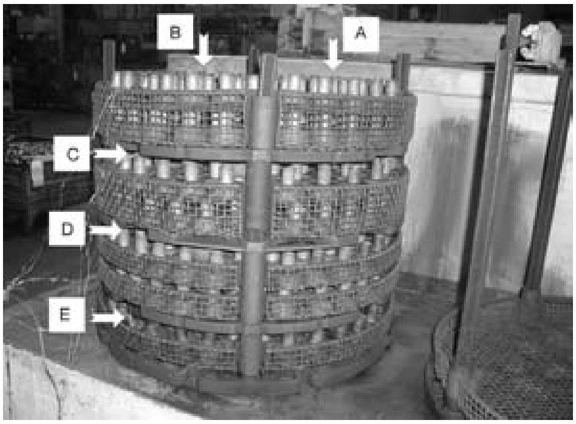

Fig. 3. The positions of the samples in the testing charge

The basket holding the forgings has the form of a cylinder, of dimensions: diameter 780 mm and length 680 mm. The basket can hold approximately 700 forgings, which results in the whole charge mass of some 220 kg, and together with basket approximately 325 kg.

The heat treatment in the case given is case hardening [14] which consists of carburizing and hardening. The prescribed time schedule of the heat treatment process is divided in three phases:

- heating,
- superheating, and
- cooling down (hardening) phase.

The first phase is an even heating of the charge [15] up to the temperature 920 ^{o}C (the prescribed time of heating ranges from 2.5

to 3 hours). The time set for superheating of the charge in the furnace at 920 °C is 5.5 to 6 hours. The cooling down phase (hardening) of the whole charge follows in the mineral oil (OLMAKAL Rapid 90) with the initial temperature 80 °C approximately 10 minutes.

For the recording of the temperature measurements results a 3-seconds time interval was selected. The ambient temperature cca. 1.5 m from the furnace was measured in the same time intervals on the sixth measuring channel. Complete results of the temperature measurements performed in the heat treatment of the testing charge of the cold formed steel pinions are shown in Figure 4.

2.2. Heat treatment analysis

The efficiency and quality of the heat treatment was analysed with the use of:

- chemical analysis (Table 1),
- hardness measurements,
- measurements of carbon and sulphur content in the case hardened surface layer, and
- metallographic examination methods.

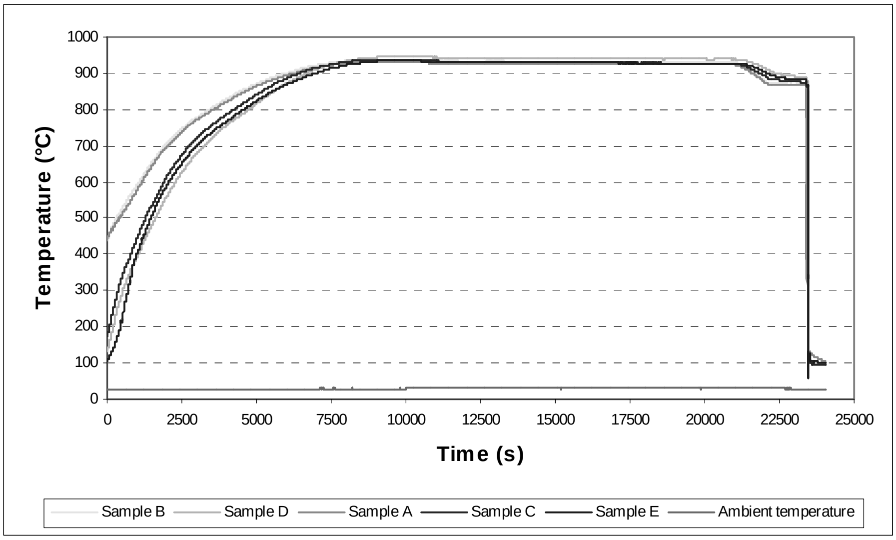

Fig. 4. Temperature measurements – testing charge

Table 2.
Hardness through the case hardened surface layer (average values of 10 measurements)

Sample	Hardness (HV1)									
	0.1 mm	0.2 mm	0.3 mm	0.4 mm	0.5 mm	0.6 mm	0.7 mm	0.8 mm	0.9 mm	1.0 mm
A	854	839	838	800	751	684	615	564	524	491
B	846	847	840	824	749	698	630	578	531	498
C	843	805	784	744	658	647	585	548	523	503
D	824	778	740	696	656	602	565	528	509	497
E	861	860	854	827	786	734	669	613	573	534

Table 3.
Carbon and sulphur content in the case hardened surface layer of the samples A, C and E

Sample	Element	(Mass. %)									
		0.1 mm	0.2 mm	0.3 mm	0.4 mm	0.5 mm	0.6 mm	0.7 mm	0.8 mm	0.9 mm	1.0 mm
A	C	0.891	0.771	0.745	0.787	0.776	0.744	0.728	0.743	0.724	0.710
	S	0.072	0.032	0.031	0.032	0.030	0.031	0.031	0.030	0.029	0.026
C	C	0.742	0.689	0.658	0.653	0.631	0.569	0.507	0.503	0.448	0.395
	S	0.052	0.035	0.033	0.028	0.028	0.028	0.028	0.029	0.028	0.028
E	C	0.814	0.696	0.683	0.673	0.678	0.599	0.620	0.618	0.630	0.613
	S	0.057	0.029	0.029	0.028	0.027	0.022	0.021	0.028	0.028	0.027

Surface hardness of the testing samples was measured with the Rockwell method (HRC). The measured values were all higher then 62 HRC (between 62.5 and 67.1 HRC). In the Table 2 are presented the results of the hardness measurements through the case hardened surface layer, and in the Table 3 a carbon and sulphur content in the case hardened surface layer.

In the frame of our experimental work also non-destructive metallographic examination by optical microscopy (OM) and scanning electron microscopy (SEM) was applied. In the Figure 5 we can see the microstructure (martensitic) of the surface layer of the tooth, and the crack through the surface layer at the tooth of the sample D. The crack length is approximately 650 μm.

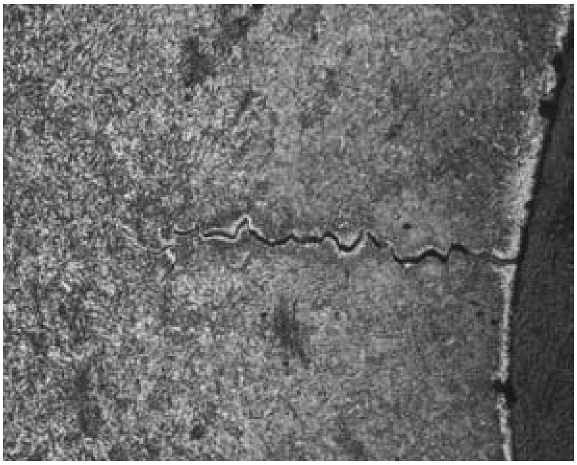

Fig. 5. Tooth – sample D. Surface layer, crack through the surface layer; magn. 500x; OM

3. Conclusions

A gas furnaces and devices play important role in the heat treatments of various metal parts for the automotive industry. Their thermotechnical characteristics have a great influence on the both: product quality and costs. In our case the efficiency and quality of the heat treatment optimisation was analysed with the use of: chemical analysis, microhardness measurements, measurements of the carbon and sulphur content in the surface layer, and metallographic examination methods.

The practical result of the before described heat treatment are the cold formed steel pinions with the surface hardness of approximately 65 HRC, and the case hardened depth of the surface layer (with hardness higher then 551 HV1) approximately 0.7 mm.

On the basis of the results of our engineering work and economical studies, the instalation of the second device (of the same producer, type and capacity) for the heat treatment was done at the end of last year.

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