Experimental research upon the durability in exploitation of the Adamite type rolls

I Kiss¹, C Pinca Bretotean¹ and A Josan¹
¹University Politehnica Timisoara, Faculty of Engineering Hunedoara, Department of Engineering and Management, Hunedoara, Romania

E–mail: imre.kiss@fih.upt.ro

Abstract. Currently, many aspects of the thermal regime of lamination are still not enough studied, and also, there are no efficient methods for the determination and adjustment of the rolls temperatures from the industrial rolling mills. The intensification of the lamination process directly influences the durability of the rolls, these being the most solicited organs of machines from whole ensemble of the lamination equipment's. Therefore, the increase of the duration of exploitation and remove of the damages through the accidental rupture of rolls, the attenuation of rolls thermal fatigue, the avoiding of thermal shock and their rational exploitation are actuality issues that must be continuously researched. The research on the durability in exploitation of rolling mill rolls represents an important scientific and economical issue. The study represents a detailed approach of the influence of some technological factors (chemical composition) on the durability in exploitation of Adamite type rolls and suggests solutions meant to increase the durability of the rolls in exploitation. The research uses data collected from the industrial use at the Faculty of Engineering – Hunedoara, as well as laboratory experiments carried out on a unique, complex and original installation. In this sense, the paper propose to present some results a series of researches and experiments of durability on testing lots, through the laboratory experiment, in distinct series, that represent the object of the laboratory research methodology.

1. Introduction

The manufacture of rolls is in continuously perfecting, the requirements for superior quality rolls are not yet completely satisfied. In many cases, the absence of quality rolls prevents the realization of quality laminates or the realization of productivities of which rolling mills are capable [1–7]. Hot rolling rolls are the parts most subjected to wear in the rolling trains because the incandescent rolled material is plastically deformed between the water–cooled rolls (Figure 1) [1–7]. The solicitations from rolls have a cyclic character, they are produced to each rotation of rolls, and the tensional status is, mainly, the outcome of the fields of asymmetrical and symmetrical temperatures actions, which produce the thermal fatigue on the surface and in the superficial layer of the hot–rolling rolls [1–7]. Thus, the research of thermal fatigue of rolls represents one of the special problems, both from scientifically, as well as from economic point of view.

It is noticeable that approximately 1/8...1/10 of the rolls are removed from exploitation because of the thermal shock caused breakings, which cause accidental damage and stoppage. Having in view the statistical date calculates for 10 years, the totally rolling rolls consumption represent 0.785…0.8 kg/ton of rolled steel. The losses expand over the rolls cost, as well as production losses, disturbing the
entire technological flux [1–7]. In this sense, durability in exploitation is extremely current, both for immediate practice and for the scientific research attributed to the rolls [1–14].

The technological processes of the rolls manufacture, as well as the quality of used materials have a quick extension, materialized in worldwide market competition, through exceptional qualities of rolls. The technological manufacturing process of the rolling mills rolls, as well as the quality of material used in manufacturing them, can have a different influence upon the quality and the safety in the exploitation. These researches are approaches of the quality assurance of the rolling rolls, from the viewpoint of the quality of materials, which feature can define the duration and the safety in exploitation [1–13]. The research on durability in exploitation of hot rolling mills rolls assures relevant conditions for the appropriation of the research methods of the thermal regimes that are submitted the rolls that works in variables thermal solicitation conditions [1–13].

The problem of durability in exploitation of the rolls has been studied for its importance in the rolling industry [1–14]. The durability tests are used to predict the rolling rolls performance and to optimize the roll’s material during the manufacturing (casting) process and also to provide insights into control strategies that may improve the rolls performance.

Many studies have been reported on the durability in exploitation, in the last 10–15 years [1–14]. Most of the studies reviewed above investigated different type of materials and follows the characteristics of material destined to the rolling rolls, on a unique, complex and original installation. [2,7–13] The study of durability in exploitation of steel rolls have established a novelty, from the point of view of fundamental scientific research, theoretical and experimental, as well as from economic point of view [2,7–13]. In this sense, the experimental series on different testing lots have represent the object of the laboratory research methodology, and can be adapted for all type of rolls [2,7–13]. Studies have included both steels intended exclusively for the rolls manufacturing (55VMoCr12, 90VMoCr15 and 65VMoCr15) [2,7,8,13], irons (half–hard nodular cast iron and hard grey cast iron) [2,7,13] and a hypereutectoid steel (OTA3) [2,7,13,14].

The mode in which a material behaves differently to same thermal fatigue solicitation, from the point of view of chemical composition was studied in [2,8–14], on the same original installation. In this sense, the experimental research, in premiere, of an important number of thermal solicitations produced by the fields of symmetrical and asymmetrical temperatures over some samples of cast–iron was studied.

In all the above studies, the durability of materials worked in the same thermal fatigue solicitation has been considered [2,7–14]. The laboratory experiments demonstrated that an optimal determined chemical composition, and a good choice of materials, could assure both the wear resistance (through the hardness), and a proper behaviour in the thermal fatigue solicitations [2,8–13]. Here we have made an attempt to study the Adamite type rolls durability, in the same solicitations. These researches results lead to direct conclusions about the Adamite type rolls, and allowed their comparison with date about steel and cast–iron rolls, previously studied.
Therefore, it is recommended to use the most rational and economical materials, as well as new, more performing materials to manufacture hot rolling mill rolls [2]. A good choice of materials, properly manufactured, can constitute a technical efficient way to assure the exploitation properties of the rolls, the material from which the rolling rolls are manufactured having an important role in this sense.

2. The durability installation
The research uses data collected from the industrial use at the Faculty of Engineering Hunedoara, as well as laboratory experiments carried out on a unique, complex and original installation [2,7–13]. Figure 2 presents the construction plan of the installation for determining the durability of the hot rolling mill rolls. This installation provides the possibility of further studies and also to establish the durability in exploitation for all types of rolls used presently in industrial mills [2,7–13].

The durability results are obtained experimentally, in a research laboratory belonging to the Faculty of Engineering Hunedoara [2,7–13]. The experiments are made on groups of six rings, with a 250 mm exterior diameter, carried out from the studied types of industrial rolls. Having in view the research, three armatures of specimens were made, each with six rings and every ring made of hypereutectoid steel, Adamite type (OTA3). These rings were subject to different cyclical thermal solicitations, which, during the period of a rotation of the main axis, on one hand warm up in an electric furnace at different temperatures, and on the other hand cool in different environments, respectively in air, water and carbonic snow jets [2,7–14].

Figure 2. The construction of the durability installation [2,7–14].

During the experiments, after a certain number of stress cycles, the surface of the sharp sides of the rings presents signs of cracks because of the thermal fatigue. They appear at different intervals during the stress, intervals according to which the number of cycles is to be established. These cycles differ, depending on the type of materials studied. After establishing the number of stress cycles, until the first thermal fatigue caused cracks appear, durability histograms are done to each type of material, used to manufacture rolling mill rolls and to each type of stress [2,7–13].

3. Working regimes
From the study of the thermal regime of the hot rolling rolls, was adopted the minimal value for the rotation number of the try–outs constrained to durability test being as 30.6 rot/min, producing the highest thermal fatigue because the thermal tensions appearing as effect of temperature variations are maximal and, after a relative small number of rotations, appear the first thermal fatigue cracks [2,7–13].

In order to increase the number of the loading cycles, until the first thermal fatigue cracks appear, we have tried to maintain as high as possible temperature for try–outs, and the cooling fast and accentuated. Each of the three sets of try–outs consisting in six rings were constrained to a working
regime, pursuing the calculated moment of the appearance of the thermal fatigue first cracks, registering the number of loading cycles.

Based on the previous data presented, three experimental thermal regimes are adopted, having the main elements presented in Table 1. The order of the experiments was regime A, B and C [2,7–13].

### Table 1. The experimental thermal regimes [2,7–13].

| The characteristic elements from the experimental regime | Experimental regimes |
|----------------------------------------------------------|----------------------|
| Rotation number of the try–outs mounted on the main axle, [rot / min] | 30.6 | 30.6 | 30.6 |
| The temperature of the electric furnace medium, [°C] | 910±10°C | 910±10°C | 910±10°C |
| The cooling medium, [–] | air | circulated water | carbonic snow |

During the durability experiments, after the A, B and C regime, applied separately for each set of try–outs formed of six rings, representing the 6 studied cast hypereutectoid steel, Adamite type (with different chemical compositions), aiming by visualization the appearance of the first thermal fatigue cracks. These first thermal fatigue cracks appear on the sharp lateral exterior edges at a Φ250 mm maximal diameter, on each ring assembled in the packing, after a certain determined number of thermal loading cycles [2,7–13]. The visualizations made in order to observe the thermal fatigue cracks were made twice per day, calculating the number of cycles passed after the each visualization.

### 4. Results & Discussions

From the point of view of the materials used in the durability tests, we have the following remarks:

— we uses heating–cooling solicitations in different thermal regimes, subdued the analysis hypereutectoid steels samples from rolling rolls, after the realization of the hot–roll campaigns in the roughing stands sectors, having different chemical compositions obtained by casting.

— each of the six samples of hypereutectoid steel from which the rings are manufactured, behaved differently to the thermal fatigue solicitations, although technological they do the part from one the group of rolling rolls type (Adamite type rolls), used in the roughing stands sectors;

— the determined chemical compositions (the basic and alloying elements) of the six samples of hypereutectoid steels included in the recent study, are presented in the Table 2.

— the measured hardness of the Adamite type rolls (on the body and on the two necks), in the Table 2 are presented too.

### Table 2. The chemical composition and the hardness of the hypereutectoid steel, used in manufacturing of Adamite type rolls (OTA3 type).

| TYPE | No. | Chemical composition, [%] | Hardness, [HB] |
|------|-----|---------------------------|---------------|
|      | C   | Si | Mn | S  | P  | Ni | Cr | Mo | body | necks |
| OTA3 | 1   | 2.02 | 0.70 | 0.91 | 0.019 | 0.031 | 1.66 | 1.22 | 0.45 | 412  | 333  |
|      | 2   | 1.99 | 0.71 | 0.92 | 0.015 | 0.033 | 1.58 | 1.24 | 0.39 | 401  | 329  |
|      | 3   | 1.88 | 0.65 | 0.81 | 0.017 | 0.031 | 1.33 | 1.19 | 0.33 | 380  | 318  |
| OTA3 | 1   | 1.78 | 0.58 | 0.79 | 0.022 | 0.039 | 1.29 | 1.19 | 0.31 | 369  | 302  |
|      | 2   | 1.72 | 0.62 | 0.74 | 0.018 | 0.028 | 1.27 | 1.28 | 0.33 | 349  | 288  |
|      | 3   | 1.68 | 0.60 | 0.66 | 0.028 | 0.036 | 1.23 | 1.36 | 0.34 | 337  | 276  |
After the experimental exploiting durability tests, evaluated in thermal loading cycles, were made durability histograms, for each loading regime and for each mark of studied material, the results being presented in Figure 3 (Table 3).

**Table 3.** The number of thermal cycles and cyclical thermal solicitation regimes.

| No. of rings | Type of rolls | Number of thermal cycles / The cyclical thermal solicitation regimes |
|--------------|--------------|------------------------------------------------------------------|
|              |              | Regime A | Regime B | Regime C |
| 1. OTA3      | 249 \cdot 10^3 | 223 \cdot 10^3 | 196 \cdot 10^3 |
| 2. OTA3      | 244 \cdot 10^3 | 219 \cdot 10^3 | 188 \cdot 10^3 |
| 3. OTA3      | 221 \cdot 10^3 | 211 \cdot 10^3 | 172 \cdot 10^3 |
| 4. OTA3      | 229 \cdot 10^3 | 217 \cdot 10^3 | 176 \cdot 10^3 |
| 5. OTA3      | 219 \cdot 10^3 | 203 \cdot 10^3 | 167 \cdot 10^3 |
| 6. OTA3      | 213 \cdot 10^3 | 197 \cdot 10^3 | 162 \cdot 10^3 |

Regarding the working regimes applied to the six rings used in the durability tests, we have the following remarks:

— in the first experiment, we adopted an loading regime (thermal stress regime A, in air), in which the materials under study resisted longest at stress cycles, until the first thermal fatigue cracks appeared;

— in the second experiment, we adopted an medium regime (thermal stress regime B, in circulated water), in which the first thermal fatigue cracks appeared in a smaller number of stress cycles;

— in the third experiment, we adopted a heavy regime (thermal stress regime C, in carbonic snow), in which the thermal fatigue cracks appeared at the lowest number of stress cycles.

Analysing the durability test results, we have the following observations:

— the hypereutectoid steel of the rings no. 1 and no. 2 had best behaviour to the thermal fatigue, these supporting 249000 thermal cycles in the loading regime (regime A), respectively 244000 cycles for same regimes of solicitation; In the medium regime (regime B), these rings supported 223000, respectively 219000 cycles; In the heavy regime (regime C), these rings have also a good behaviours, they supported 196000, respectively 188000 cycles until the first thermal fatigue cracks appeared;
— the hypereutectoid steels of the rings no. 3–6 behaved all in a satisfactory ways, having a relative similar behaviours, better for the ring no. 4, which supported 229000 thermal cycles in the loading regime (regime A), 217000 cycles in the medium regime (regime B) and 176000 cycles in the heavy regime (regime C).
— the most dissatisfactory behaviour, however, was fallen across hypereutectoid steel of the ring no. 6, this supporting 219000 cycles in the loading regime (regime A), 197000 cycles in the medium regime (regime B) and 162000 cycles in the heavy regime (regime C);

5. Conclusion
The laboratory experiments demonstrated that an optimal determined chemical composition could assure both the wear resistance (through the hardness), and a proper behaviour in the thermal fatigue solicitations. Consequently, the chemical composition can assure both the hardness of the rolls, and the durability in thermal fatigue conditions.

The research on the durability in exploitation of the hot rolling mill rolls is to be extended further on different brands of steels and irons used for the manufacturing of hot rolling rolls, depending on the durability up to the point of fissures and thermal fatigue cracks. Therefore, it is recommended to use the most rational and economical materials, as well as new, more performing materials to manufacture hot rolling mill rolls.

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