



## SURFACE HARDENING FOR 38MoCrAl09 STEEL USING FLUIDIZED BED NITRIDING

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### ABSTRACT

*The paper is based on nitriding experiments made in a fluidized bed laboratory furnace. Fluidization was obtained in a steel refractory retort by solid granular (burned fire clay) and fluid (mixture of ammonia and nitrogen). Heating system is based on indirect electrical method. Heating transfer from furnace to retort is high and is determinate by high value of heat transfer coefficient for fluidized bed. Nitriding processes were driven by a classic experimental matrix (ammonia proportion is constant, nitriding time and nitriding temperature are variable). Results were investigated by: hardness HV<sub>s</sub>, micro-hardness HV<sub>0,05</sub>, microstructure and XRD. The results confirm nitriding process, media capacity for heat and mass transfer and a good behavior of 38MoCrAl09 steel.*

KEYWORDS: fluidized bed, nitriding, nitraalloy steel, short time

### 1. Introduction

After nitriding treatment, superficial layer with special properties (high hardness) simultaneously with a reliable core will offer to part exploiting exceptional properties (fatigue and wear resistance, tenacity). For increasing quality for treated machine parts, different techniques have a rapid developing, diversification and adaptability to product processes. Fluidized bed technology (FBT) offer an active media to thermochemical treatments at low investment costs, [0], [0]. For FBT applications with open furnace, technological costs for gases increase, [0].

Some limitations for shape parts are important too. Simple surfaces in vertical/axial positions are recommended for uniformity of treatments. Important mechanical gas solid processes (fluidized bed gasdynamics) having high influences over mass transfer and heat transfer processes are shown in Fig.. High surfaces for solid/gas interfaces are an important characteristic for fluidized bed.

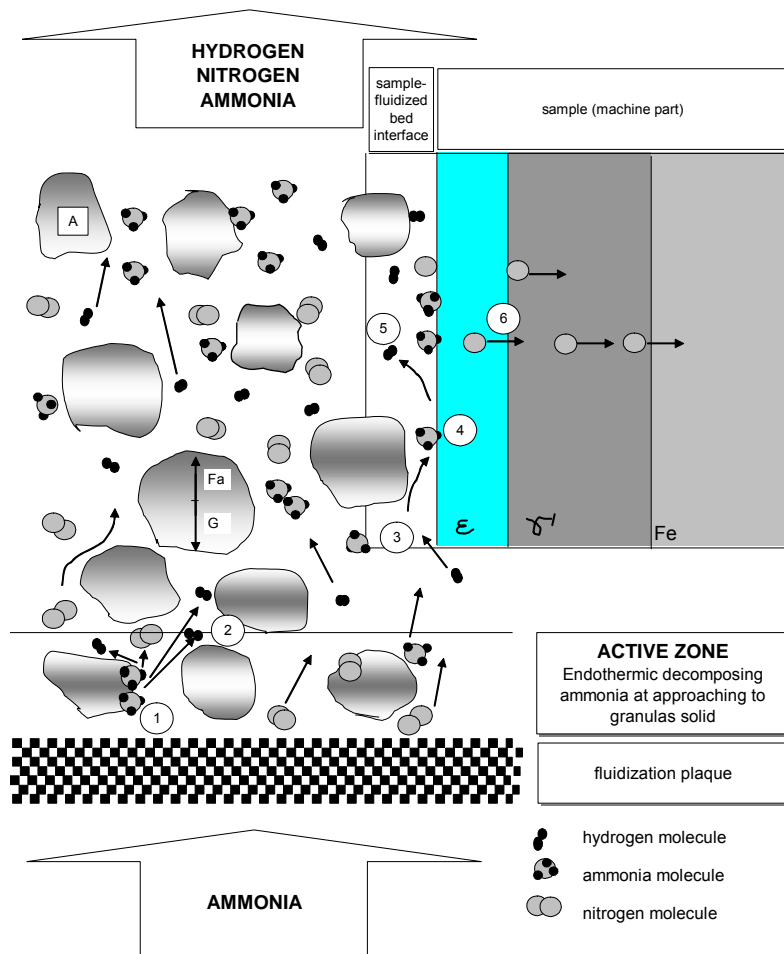
### 2. Experimental conditions

For nitriding in fluidized bed experiments we used a pilot furnace (Fig.2).

Some important characteristics were:

- fluidized bed furnace (140mm diameter, H/D=1,2)
- heating technique: indirect electrical heater
- solid granular: burned fire clay with granulation 0,010...0.016mm
- fluidization gas: mixture from ammonia (33%) and nitrogen (rest)
- samples: 38MoCrAl09 steel (Table 1)
- experimental procedure: classical "full factorial" array with two factors and three level for each factor.

Many factors have influence over nitriding process but nitriding temperature and nitriding time are present for all nitriding technologies. Some fluidization factors were fixed by preliminary experiments at constant values. Fluidization was conducted driven by diagram pressure drop/velocity [5] but process repeatability is important. Gas mixture debit was constant for all nitriding regimes and visual observation was important for quality of fluidization. One of the most important factors influencing the quality of fluidization is the uniformity of gas flow across a constant pressure drop [3]. A drop pressure in fluidized bed was measured by "U" manometer. Samples had a disc shape and were immersed vertically in fluidized bed.



**Fig.1.** Representation of processes on fluidized bed nitriding: A-solid, G-weight, Fa- ascension force, 1- endothermic decomposing ammonia, 2-hydrogen molecule formation from atoms (similarity to nitrogen), 3-ammonia molecules approaching the surface, 4-endothermic decomposing ammonia, 5- hydrogen molecule formation from atoms, 6-nitrogen atoms diffuse into metal surface

**Table 1.** Chemical composition for 38MoCrAl09 steel (nitralloy steel, mass %)

steel	C	Mn	P	S	Si	Mo	Cr	Ni	Al
38MoCrAl09	0,41	0,53	0,22	0,011	0,33	0,18	1,35	0,11	0,86



**Fig.2.** Image with nitriding furnace.

**Table 2.** *Experimental regimes for 38MoCrAl09 nitrided in fluidized bed*

Exp. no.	Chemical composition of gas mixture	nitriding temperature	nitriding time
m.u.	%	°C	h
1	33%NH <sub>3</sub> +67%N <sub>2</sub>	520	1
2			2
3			3
4		550	1
5			2
6			3
7		580	1
8			2
9			3

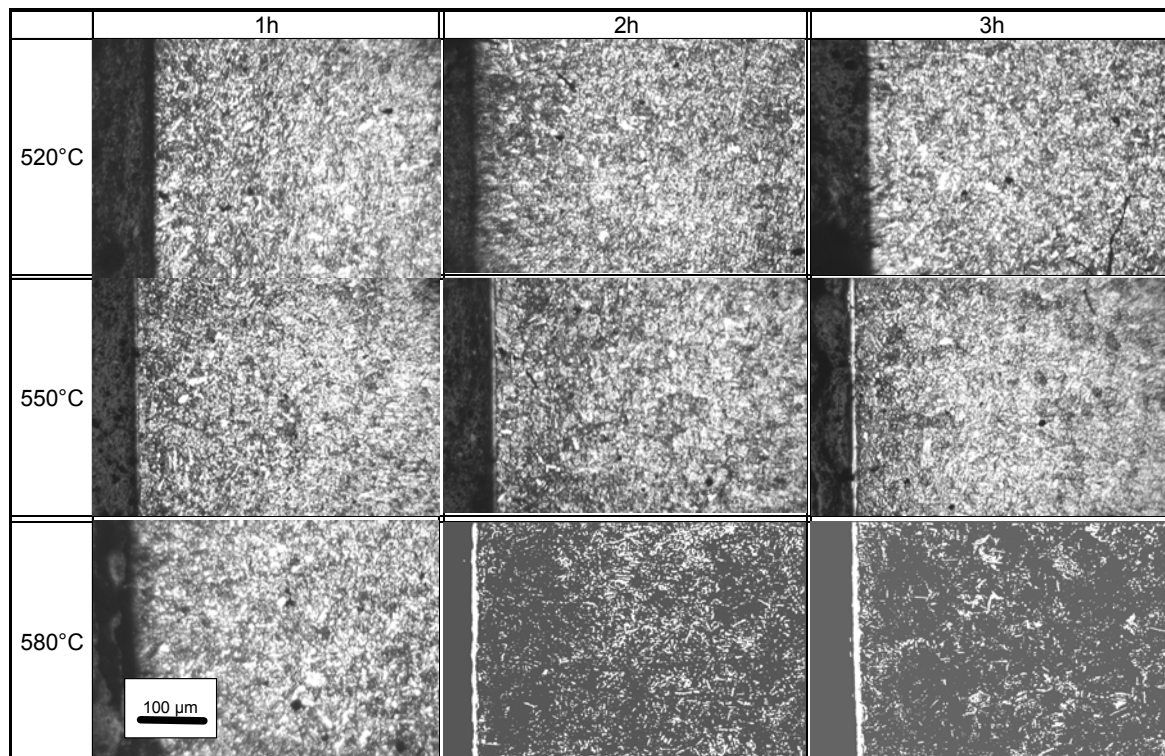
### 3. Results and discussion

Results were investigated by: hardness HV<sub>5</sub>, micro-hardness HV<sub>0,05</sub>, microstructure and XRD. Microstructures of all samples (Fig.3, 38MoCrAl09 steel), shown nitrided layers. By increasing nitriding temperature and nitriding time, a combination layer

formation is present. HV<sub>5</sub> measurements over nitrided surfaces for all regimes showed an appreciable hardness increasing.

For 550°C and three hours hardness is over 1200 daN/mm<sup>2</sup> (Fig.4).

Total nitriding layer depth for all nitriding regimes by micrographic measurements is shown in Fig.5.

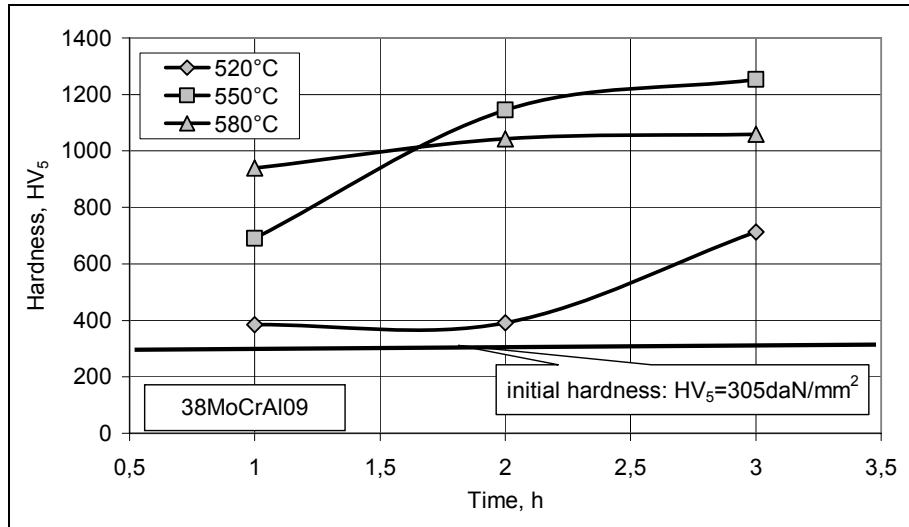


**Fig.3.** *Micrographs of nitrided 38MoCrAl09 steel samples after experimental regimes [1].*

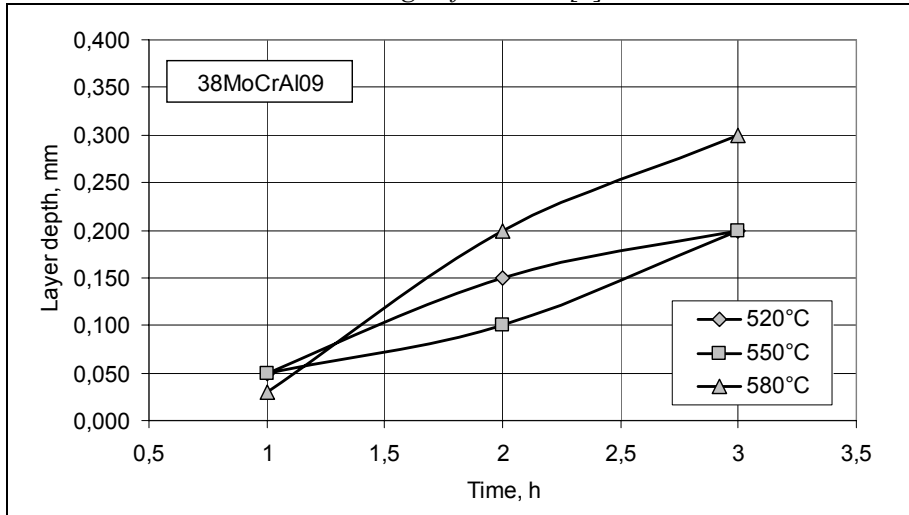
All 38MoCrAl09 steel samples shown nitriding layers. A combination layer is present. By increasing nitriding temperature and nitriding time a combination layer is present and that increasing by nitriding time. Diffusion layer has for three hours Hardness HV<sub>5</sub> measurements on the nitriding surfaces shown an appreciable increasing for all regimes.

The presence of specific nitriding phases was investigated by XRD (DRON 3) and for 550°C nitriding temperature and one hour nitriding time, the diagram is shown in Fig.7.

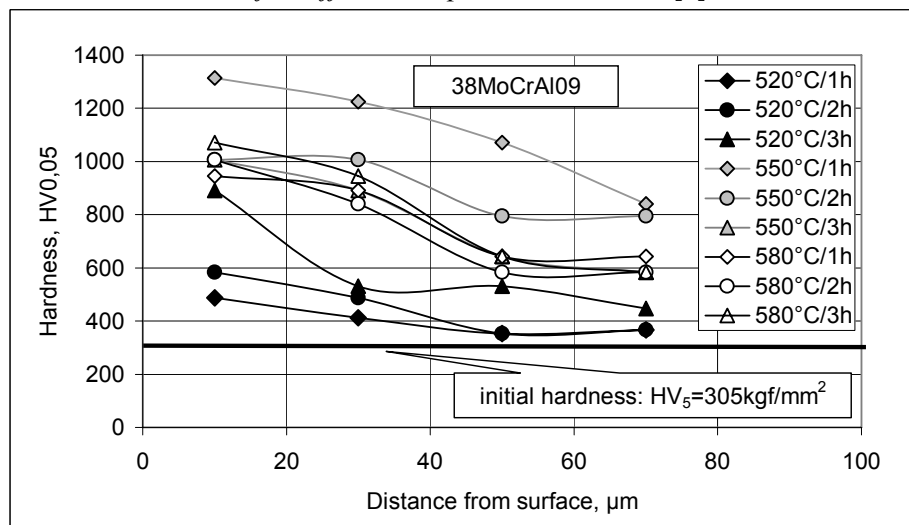
The XRD investigation gives only the phases presence, [6].



**Fig.4.** Hardness  $HV_5$  on the nitriding surface for 38MoCrAl09 steel samples after nitriding in fluidized, [1].



**Fig.5.** Total nitriding depth layer for 38MoCrAl 09 sample nitriding in fluidized bed for different temperature and time, [1].



**Fig.6.** Micro hardness  $HV_{0,05}$  for 38MoCrAl09 steel sample, [1].



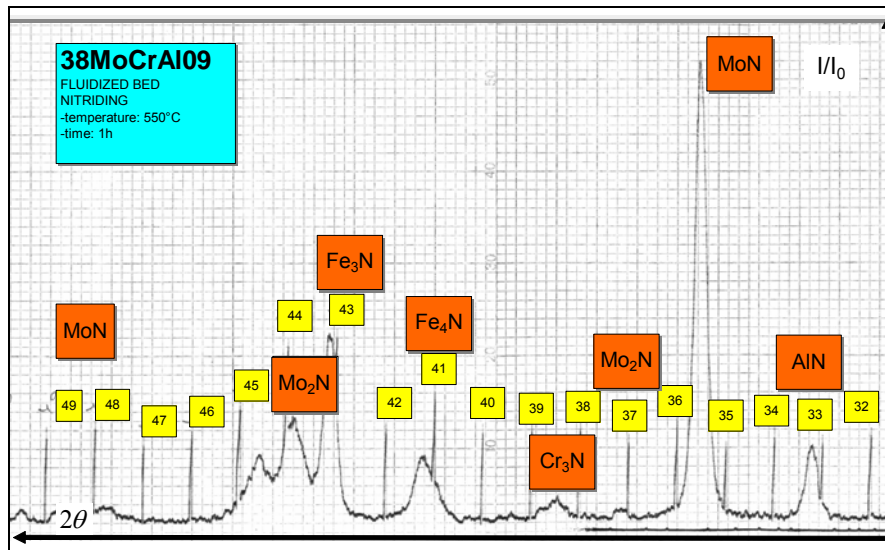


Fig.7. XRD investigations by DRON 3

The steel has in chemical compositions Mo, Cr and Al that conducted to hard phases at nitrogen presence and temperature. Because fluidized bed has a high thermal and mass transfer coefficient the specific nitriding phases were formed for one hour nitriding time and 550°C nitriding temperature.

nitriding time. By adequate selection of steel [7] and fluidization factors, nitriding in fluidized bed is characterized by a short total time of treatment that increases efficiency of process. Some limitation of part shapes and positions in fluidized bed are available for industrial applications.

## Conclusions

The results investigated confirm nitriding process in fluidized bed, media capacity for heat and mass transfer and a good behavior of 38MoCrAl09 steel. Nitriding in fluidized bed process is characterized by a short time cycle (1...3h) because in experimental conditions we used an open furnace. The cooling process is shorter when comparing nitriding processes with other nitriding technologies; that increasing efficiency, [3]. The gas mixture after nitriding reactions containing hydrogen and rests of ammonia; that was burned in atmosphere at nonpolluting gasses (carbon dioxide and steam). For low alloyed steel with Cr, Mo and Al the hardness on surface (HV<sub>5</sub>) had 700... 1250 daN/mm<sup>2</sup> for 550... 580°C and 1...3 hour

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