LASER HARDENING OF STEEL C45
TĒRAUDA C45 LĀZERRŪDĪŠANA

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Abstract. *The aim of the work is to analyze possibility to replace induction hardening process with laserhardening process in production. In metalworking production to harden the parts of steel C45 is used induction hardening method for the moment. In this work will be used experiments to show the possibility to perform laserhardening with CO_2 laser and results should show how good the results gives laserhardening to fulfil the requirements of hardening.*

Keywords: *CO_2 laser, hardening of steel C45, laserhardening, production processes.*

Introduction

Nowadays, laser has become a new heat source for the same job as typical hardening methods for example induction hardening.. Laser surface treatment can be applied in both coating and hardening in the surface treatment fields; it has many advantages compared with the traditional ways, such as smaller distortions and less post-process time.[1]

In last 10 years lasers became very significant in many branches of industry for example metallurgical engineering, steel processing, engineering industry; aviation, power engineering, automotive industry, mining engineering and drilling technology.[2]

One of the lasers' proceses what are widely used is laser hardening. Laser hardening comparing another competing methods as induction hardening, carburizing, flame hardening has many of benefits.

Laser surface treatment is a very flexible process, because of the self-quench and easily controlled laser power; it has been wildly used in automobile sectors and other industrial areas. One important application is the laser hardening, which involves only a thermal effect on the surface where a new structure with high hardness is obtained on the top surface. In most of these applications, laser does not treat the complete surface of the components but rather small local tracks. With a designed and delicate movement control system, laser hardening is suitable for some components with complex geometry, *i.e.* edges, corners and holes.[3]

Laser hardening benefits are high scanning speed, self-quenching with no need of external quenchants, low distortion of the workpiece, selectable area of treatment, less or no post-treatment required, ease for computer control and low environmental impact.[4]

To perform right laser hardening for the parts and get needed results should be many of parameters checked up what could impact the process. The laser hardening process can be influenced by many factors. The effect of hardening basically depends on the material, laser and processing parameters.

The surface hardness depends on the hardness of the martensite formed. To form martensite, the material for laser hardening should typically contain at least around 0.05 wt% carbon. The surface hardness generally increases linearly with the carbon content. [5]

The steel C45 has 0.5 % content of carbon what means that it is medium carbon steel. The high content of carbon in steel C45 what is shown in table 1 means that steel is suitable for laser hardening.

Table 1.

C	Si	Mn	Ni	P	S	Cr	Mo
0.43 - 0.5	max 0.4	0.5 - 0.8	max 0.4	max 0.045	max 0.045	max 0.4	max 0.1

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The geometry of the workpiece affects the heat flow distribution. As an empirical rule, the thickness of the workpiece should be at least ten times of the desired hardened depth so that the self-quenching can occur without significant bulk heating. The rule that the thickness of the workpiece should be at least ten times of desired hardened depth (for self-quenching process important) is noticed because the thickness of "Carrier" part what is analysed in the place where hardening should be perfomed is 28 ± 0.1 mm but desired maxium of hardness depth is 0.3 mm.

The "Carrier" material is quenched & tempered with following mechanical properties: tensile strenght Rm = 700 – 900 Mpa. This means that this type of material is very suitable for hardening proceses.

Surface max. roughness on the surfaces what should be hardened is Rz = 16, but results in production shows that after turning operation max. Rz = 7. So the hardening needed surface roughness is very small and it will give some impact to hardening proceses.

As different kinds of steels absorb CO2 laser beam radiation with quite a low efficiency (around 2-5%), traditional CO2 laser hardening of steel requires surface coating before the treatment to increase the absorption of laser energy. [6]

Laser power density against beam interaction time is very important to perform laser hardening. The laser power density used in laser hardening is usually around 103 -105 W/cm^2, which is relatively low among laser processes.

The traverse speed strongly affects the time of laser irradiation received by the material. Laser power density in an order of 103 -105 W/cm^2 with a typical interaction time of 0.1-0.3 seconds can produce martensite structure in steel. As the beam length in the traverse direction is determined by required laser power density and the track width, the traverse speed can be calculated by dividing the beam length with the interaction time. The traverse speed is normally the parameter that is fine-tuned to optimize the process in order to obtain the required hardened depth and degree of homogenization.

In this paper there is taken production case of real existing metal working production company what supplies components such us shafts and gears for automotive customers.

Company produces part "Carrier" and in the production process one of the customer requirements is that part should have definite hardness in particular depth for concreate places on part. So there is hardening needed as one of part production steps.

The hardening requirements for part "Carrier" is:

- 350 – 600 HV (Vickers)
- Rht (hardening depth) 0.03 – 0.3 mm.

The width of surface on one side of part is 9 mm and on second side of part the width what needs hardening is 14 mm, shown in Fig1.

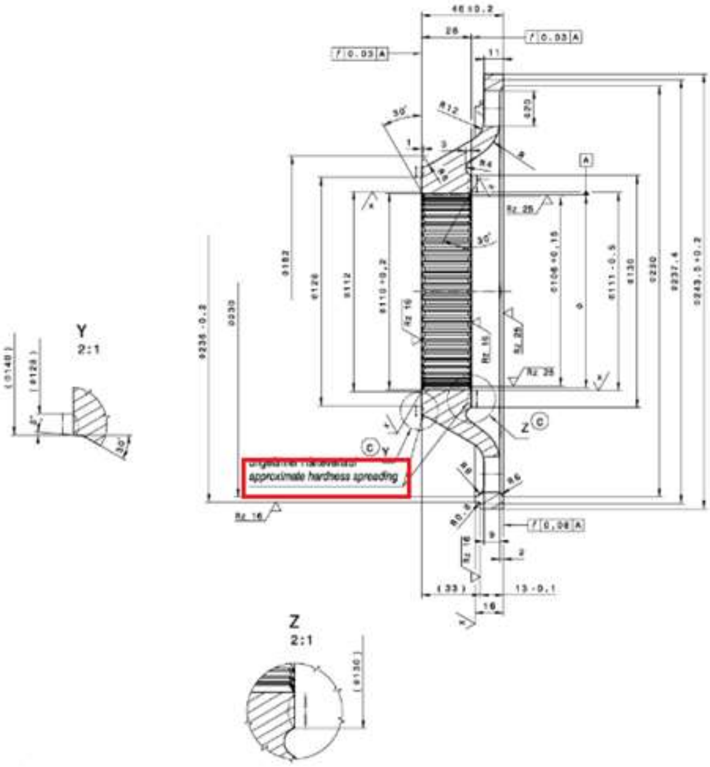


Fig 1. **Drawing of part with hardening requirements**

Materials and methods

CO_2 laser CHANXAN CW-1325 with max. power 150W and laser beam shape - Gauss was used to perform laserhardening for steel C45 and 7 experiments were done to see the effectiveness of laser hardening.

There was laser scanning used to run the tests. 3 parameters of laser process were used: power, laser scanning rate and feed rate. The combination of mentioned 3 parameters in every of experiments is given in table 1.

Table 2.

Number of experiment	**Power, W**	**Scanning speed, mm/s**	**Feed rate, mm^2/s**
1.	23	20	0.01
2.	23	40	0.01
3.	23	60	0.01
4.	30	40	0.01
5.	60	40	0.01
6.	30	20	0.01
7.	30	60	0.01

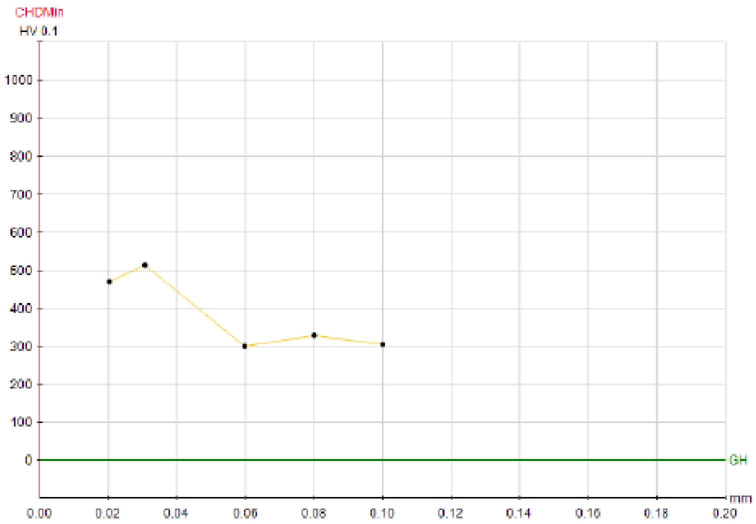
The power of laser was used not fully because using power more then 60 W the engrawing process was started what means that surface of workpiece has been destroyed what is not acceptable for production.

Experiments were carried out at temperature 20 °C in the room and temperature of workpiece was 19 °C. Measured temperature in the process time on the workpiece was over 500 °C. The hardness of material of workpiece is 260 HV or 26 HRC.

Results

To examinate the results after experiments there was used Microhardness measurer - Qness Q30A. HV 0.1 was used as a method to evaluate microhardness. After the examination of all 7 experiments on microhardness measurer the best results have eksperiments 2; 5 and 7.

The results of mentioned three exsperiments give the best results thatsway is also analysed forward. The results of experiment 2 is shown in Fig 2.

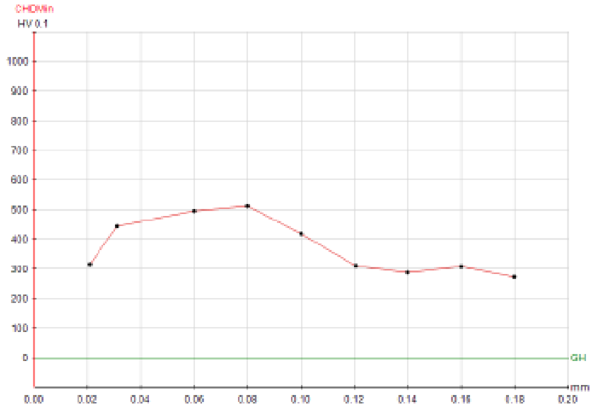


Nbr	Hardness	Method	X - Position	Y - Position
1	470	HV 0.1	0,02	0,00
2	514	HV 0.1	0,03	0,03
3	300	HV 0.1	0,06	0,00
4	329	HV 0.1	0,08	0,03
5	305	HV 0.1	0,10	0,00

Fig 2. **Results of experiment No 2**

According to the experiment number 2 results we see that highest reached hardness is 514 HV in depth 0.03 mm. But total hardness depth is 0.1 mm.

The results of experiment 5 is shown in Fig 3.



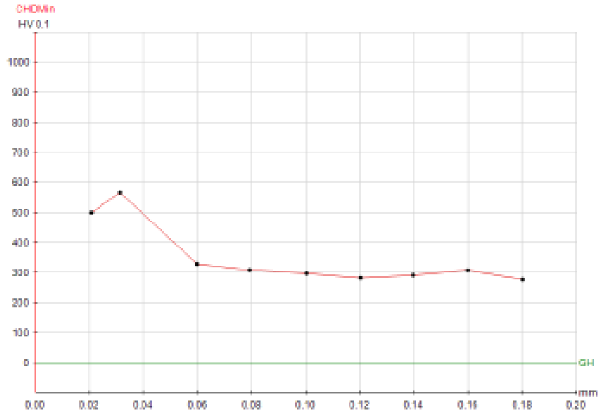
Nbr	Hardness	Method	X - Position	Y - Position
1	315	HV 0.1	0,02	0,00
2	444	HV 0.1	0,03	0,03
3	495	HV 0.1	0,06	0,00
4	512	HV 0.1	0,08	0,03
5	419	HV 0.1	0,10	0,00
6	310	HV 0.1	0,12	0,03
7	288	HV 0.1	0,14	0,00
8	308	HV 0.1	0,16	0,03
9	273	HV 0.1	0,18	0,00

Fig 3. **Results of experiment No 5**

According to the experiment number 5 results we see that highest hardness is 512 HV in depth 0.08 mm. But total hardness depth is 0.18 mm.

Results of experiment number 5 show that microhardness is achieved deeper than in second experiment however the results of hardness is just 273 HV in the last point of achieved hardness in material.

The results of experiment 7 is shown in Fig 4.



Nbr	Hardness	Method	X - Position	Y - Position
1	499	HV 0.1	0,02	0,00
2	567	HV 0.1	0,03	0,03
3	329	HV 0.1	0,06	0,00
4	308	HV 0.1	0,08	0,03
5	297	HV 0.1	0,10	0,00
6	282	HV 0.1	0,12	0,03
7	291	HV 0.1	0,14	0,00
8	307	HV 0.1	0,16	0,03
9	277	HV 0.1	0,18	0,00

Fig 4. **Results of experiment No 7**

According to the experiment number 7 results we see that highest hardness is 567 HV in depth 0.03 mm. But total hardness depth is 0.18 mm.

As in fifth experiment also in seventh experiment the microhardness is achieved in the same depth – 0.18 mm but hardness is still very low – just 277 HV.

From all exsperiments conlusion is that with highest in this case 60 W pover and highest scanning speed 40 mm/s is possible to get the best results of laser hardening in concreate case.

Although the best exsperiments shows that it is possible to to achieve the hardness on steel C45 with CO_2 laser which max power is 150 W but still the hardness is low in some hardening points. The requirements 350 – 600 HV and hardening depth 0.03-0.3 mm can be achieved but good results are not in all depths. And best results (experiment No 5) showed that with power 60 W and scanning speed 40 mm/s is possible to achieve hardness 512HV and hardening depth 0.18 mm however in the both tolerances (hardness and hardening depth) are only 4 points from measured 9. But still fifth experiment shows that this is possible to get hardness in required depth with used laser and parameters, however thre is no continual results.

Summary

Laserhardening is widely used in many industries and laserhardening of steel C45 is common occurrence. The experiments show that it is possible to harden the steel C45 with CO_2 laser however results was not continual good but showed that used laser with choosen parameters is suitable to achieve the requirements what are stated in the drawing.

Using CO_2 laser and process parameters: power 60 W, scanning speed 40 mm/s and feed rate 0.01 mm^2/s is possible to achieve very good result – hardness 512 HV in depht 0.08 mm.

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