Surface Treatment by Burnishing of S235JR Steel - Design of Experiments Approach

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Surface treatment by burnishing of S235JR steel - Design of experiments approach

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ABSTRACT

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The burnishing treatment was performed on cylindrical samples of S235JR steel. The influence of three regime parameters, namely, pressure force (Py), feed rate (f) and tool radius (r) (steel ball and diamond tip) on the roughness Ra, was studied with a complete multi-factorial 2^3 design. The relationship between these parameters and the roughness was concretized by a mathematical model allowing the prediction of the response Ra. The experimental results obtained showed that the burnishing treatment provides a good surface finish, i.e., an improvement of 88% where the initial Ra roughness value decreases from 1.786µm to 0.21µm.

1. Introduction

2. Being the most stressed in service, the surface layers are the first to be degraded by the various external stresses that often lead to the deterioration of the life of the elements [1]. Thus, a good surface finish with low roughness is more and more appreciated to guarantee high quality parts and consequently a good functioning of the mechanisms in which they work [2]. This characteristic can be improved by surface plastic deformation processes (SPD), such as mechanical surface treatments (MST), in particular mechanical burnishing [2,3].

Our work consisted in studying the surface roughness, using the method of complete multifactorial planes on cylindrical samples of S235JR steel obtained by machining on a conventional lathe.

2. Materials and method

2.1 Material

The material used is S235JR steel which is a mild steel, supplied in cylindrical bars of length L=700mm and diameter Ø=40mm. It is designed as a general purpose unalloyed structural steel, not intended for heat treatment.

The steel S235JR was used in this work, since it is widely used in the manufacture of mechanical engineering parts and in the automotive industry.

The sample for the determination of the chemical composition is prepared according to the ISO 14284 standard. The results of the chemical analysis obtained by spectral analysis at the central laboratory of the steel complex of ElHadjar, are presented in Table 1.

Table 1. Chemical composition of S235JR

% elements					
C	Mn	Si	P	Cu	Cr
0,182	0,591	0,156	0,009	0,051	0,014

Mechanical characteristics: Hv = 260; Rm=340MPa ; Re=250MPa; A=11%.

2.2 Experimental methodology

Knowing that the result of the burnishing treatment is conditioned by the control of the operation, so in order to estimate the effect of the parameters of the treatment regime on the roughness (Ra), we carried out an experimental study on cylindrical samples of steel S235JR obtained by machining on a conventional lathe of type 16K20. The influence of three main parameters of the burnishing process, namely, the pressure force (Py), the feed rate (f) and the radius (r) of the tool (steel ball and diamond tip), was shown by means of a complete multi-factorial experimental design at two levels (-1, +1) of type 2^3. The relationship between these parameters and the roughness was modeled by a mathematical model allowing the prediction of the Ra response as well as the optimization of the processing parameters.

The parameters were coded and combined together according to the experimental design (Table 2).

Table 2. Experience matrix

N° d'expérience	Py [gf] (facteur 1)	r [mm] (facteur 2)	f [mm/tr] (facteur 3)
1	−1	−1	−1
2	+1	−1	−1
3	−1	+1	−1
4	+1	+1	−1
5	−1	−1	+1
6	+1	−1	+1
7	−1	+1	+1
8	+1	+1	+1
Niveau (−)	80	2,5	0,054
Niveau (+)	240	5	0,124

(Nb: the 2.5mm radius represents the diamond tip of the tool, while the 5mm radius represents the moving hardened steel ball).

The output response (y) which expresses the arithmetic surface roughness Ra [µm] is predicted from a first degree polynomial mathematical model with interactions.

2.3 Experimental procedure

Considering the experimental design 2^3, 9 cylindrical segments were machined on a cylindrical bar of length L=300mm and diameter D=40mm on the conventional lathe 16K20 .

On this sample, segments 1 to 9 were machined (N=1400 rpm, f=0.11mm/rev, ap=0.5mm) and immediately burnished under abundant lubrication (N=560 rpm) with different parameters, while segment 10 was simply turned.

A schematic of the sample with its characteristics is shown in Figure 1, which is similar to the sample proposed by Arun Prasad et al [4].

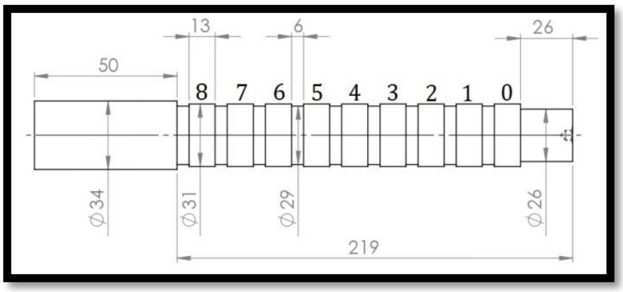

Figure 1 Front view of the sample, segments 1-9 have been turned and burnished and segment 10 just turned.

2.4 Mathematical model

Thanks to the factorial study of the parameters (Py, r and f) at two levels each (high and low), as well as the roughness results, a first degree polynomial mathematical model with interactions (Equation 1) to predict the surface roughness Ra [µm] as a function of the input factors (Xi) was established. The data were analyzed using Minitab19 software.

$$Ra = 0,5935 + 0,2283x1 - 0,2355x2 - 0,06675x3 - 0,3562x1x2 - 0,081x1x3 + 0,07225x2x3 + 0,0925x1x2x3 \quad (1)$$

3. Conclusion

- A good surface finish was achieved by the mechanical burnishing process on cylindrical segments of S235JR steel.

- The results showed a maximum surface quality improvement rate of about 88% from 1.786µm to 0.21µm.

- It was observed that for the diamond tool with small radius, it is better to use low loadings, while for the tool with the hardened steel ball of large radius, high loadings give better results.

- Using the three-factor complete design method, a mathematical model (Equation 1) for predicting the roughness Ra as a function of the input parameters (Py, r, f) in the study area has been established.

- The analysis of the coefficients of the mathematical model showed that the feed rate (f) is not a significant factor for Ra, while the pressure force (Py), the tool radius (r) as well as the interaction between (Py) and (r) are significant.

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