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Proper Selection Procedure for Steels and Heat Treatment Technology

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***Summary*-- Proper selection and proper application of heat treatment technology for the manufacture of a machine element need adequate procedures and knowledge that today become much more complex. Not only is essential prior knowledge of working conditions required temperature , environment , resistors of different types (tensile , bending, torsion , fatigue) but sometimes you need to differentiate the core properties of the surface, today requiring knowledge of a new science, " surface engineering " . In this work in the form of algorithmic thinking and applying novel aspects, some developed by the author, is intended to provide the essentials for a successful application to ensure work requirements of the element.**

***Keywords*-- Production of machine elements, heat treatment technology, Surface Engineering**

I. Development

It is not intended to work further in the selection of the steel to be used.

The existence of several publications and articles related to the issue [1-6] makes this unnecessary. By contrast will deepen around him referred to the proper selection and application of or thermal treatment technologies, as well as with regard to surface engineering [7}, as to differentiate the properties of core and surface and the relationship between them.

1.1 Volume One Or Treatment That Differ Core - Surface Properties.

The first aspect to consider in the selection of heat treatment technology to be used for the complete satisfaction of the demands of work will be designed to meet the need or not to differentiate the properties of core and surface and ensure proper interrelationship. Keep in mind from the outset that as progress in this process there may need to change the initially selected steel. This led to a first aspect algorithmic approach may well see (Fig. 1).

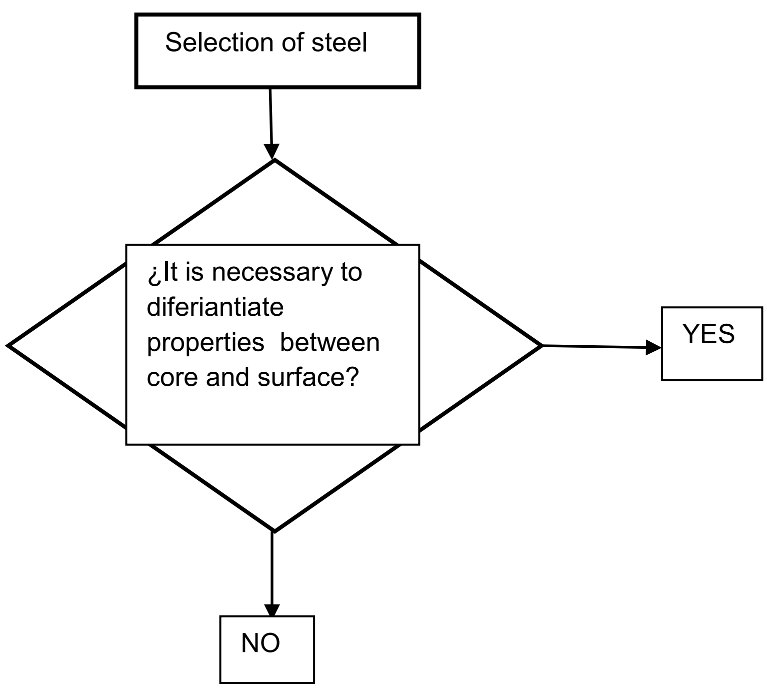

Fig . 1 Algorithmic approach in the first step of the procedure.

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Consider first the variant that is not necessary to differentiate the properties of the core and surface. In this case, the method of the technology to be used should include rigorous analysis of resistance required to ensure working conditions and this will include the structural characteristics of the material. This analysis should include:

1) What kind of applications are acting? (tensile, bending, torsion, fatigue, combined applications, there are impact loads, which is the working temperature, etc.)
2) Dimensions of the element.
3) existing manufacturing , manufacturing number of elements technological conditions.

These fed known aspects are not an essential part in the procedure presented, which provide an analysis part essentially know what amount of martensite needed in the nucleus and how this is achieved, taking into account the shape and dimensions of the piece and the characteristics of the hardening (this will be closely related to the concept of hardenability) .

The calculation of the hardenability is a technological problem well defined in many textbooks Heat Treatment [8,9]. In essence, it is part of the results of an analysis on a stop Jominy test equipment. In this assay can establish a relationship between the distance to the mild end into the standard for itself and using the normalized for the Jominy test, with maximum diameter at which you can get a 50 % martensitic transformation in steel specimen parameters in question. Yield 50 % martensitic transformation depends on the carbon content and the presence of alloying elements. In Table 1 can be seen to carbon and alloy steels average hardness may reach an area with 50 % martensite [2].

Table. I
Hardness average with 50% martensite as a function of carbon content and the type of steel.

CARBON CONTENT (%)	*HRC*	
	Carbon steel	*Alloy steel*
0,08-0,17	*-*	*25*
0,18-0,22	*25*	*30*
0,23-0,27	*30*	*35*
0,28-0,32	*35*	*40*
0,33-0,42	*40*	*45*
0,43-0,52	*45*	*50*
0,53-0,62	*50*	*55*
≥ 0,63	*55*	*60*

Table. II
Effect of the carbon concentration and the % of martensite (M) in the average hardness of hardened steel [2].

% Carbon	Hardness Rockwell C				
	99% M	95% M	90% M	80% M	50% M
0,10	38,5	32,9	30,7	27,8	26,2
0,20	44,2	40,5	38,2	35,0	31,8
0,30	50,3	47,0	44,6	41,2	37,5
0,36	53,9	50,4	47,6	44,4	40,5
0,38	55,0	51,4	49,0	45,4	41,5
0,40	56,1	52,4	50,0	46,4	42,4
0,42	57,1	53,4	50,9	47,3	43,4
0,44	58,1	54,3	51,8	48,2	44,3
0,45	59,1	55,2	52,7	49,0	45,1
0,48	60,0	56,0	53,5	49,8	46,0
0,50	60,9	56,8	54,3	50,6	46,8
0,52	61,7	57,5	55,0	51,3	47,7
0,54	62,5	58,2	55,7	52,0	48,5

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However, if you want to analyze the hardenability of any piece , the results of Jominy test are only a first step , which also requires additional considerations, and after obtaining the result , it takes a number of additional steps , that form a calculation methodologies [3,8,9] .

This paper is intended to present the methodology, using an algorithm, which was successfully used for the analysis of the hardenability of several elements.

This methodology algorithm as shown in Fig. 2.

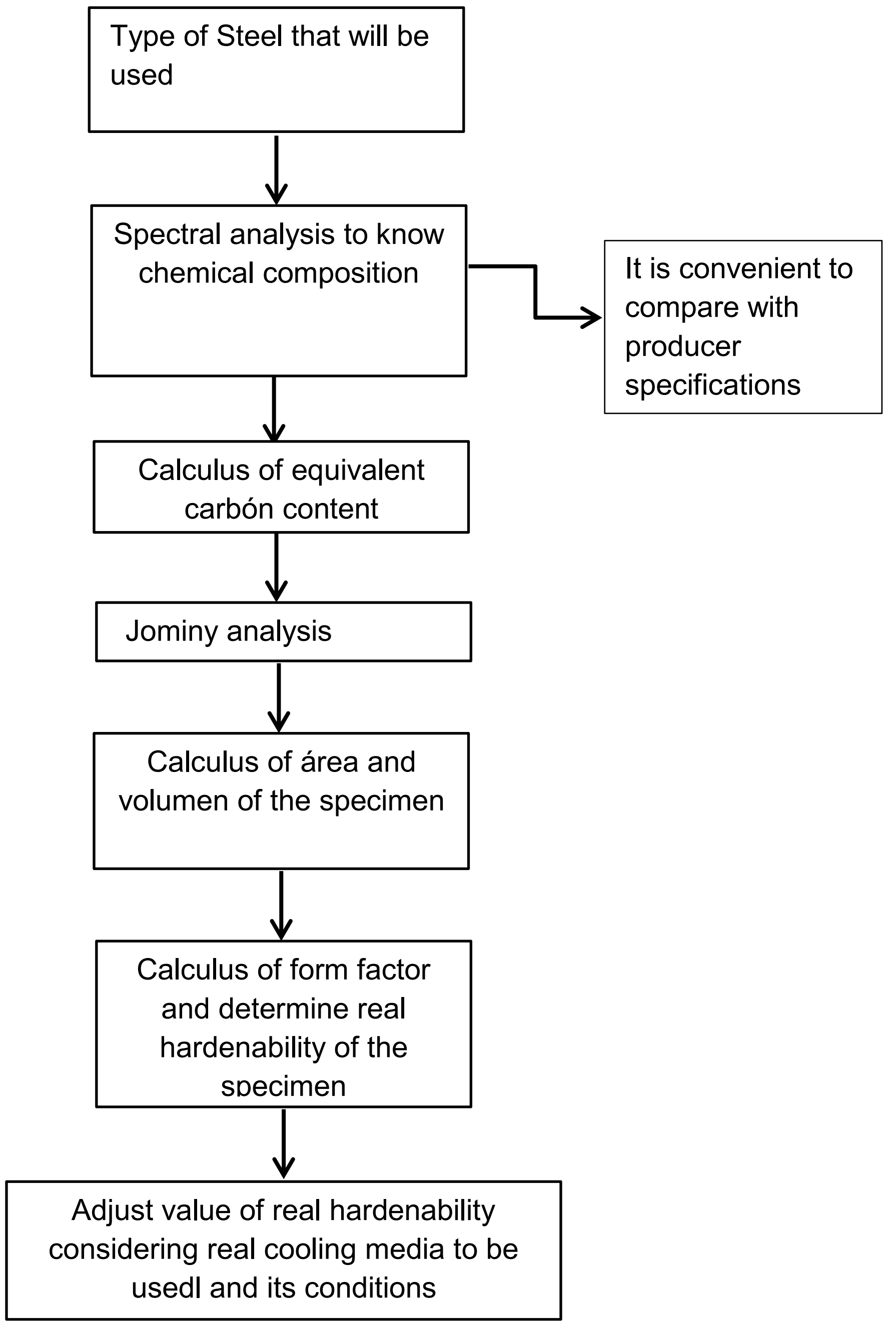

FIG. 2 Algorithm for the correct calculation of the hardenability of a piece.

In Jominiy test hardenability is L / D = 3 ratio (as the Jominy test), is achieved in that, with different cooling media, an actual full hardening (at least 50 % martensite in the core). This diameter is called ideal diameter (Di) .

As will be understood, the parts do not necessarily have this ratio (L / D = 3). To find out if any piece may have an overall hardenability form factor Kf is used.

Dp = Di • Kf (1)

Where:

Dp - is the diameter or average thickness of the piece to be obtained may full hardening.

Di - ideal diameter as the Jominy test .

Kf - form factor.

In turn, the form factor is equal to

(S / V) p = (S / V) j • Kf (2)

where:

(S / V) p - is the surface / volume ratio calculating actual piece

(S / V) j - is the surface / volume ratio Jominy specimen

Moreover, different cooling media affect the value of the ideal critical diameter (Di). This is due to several causes, but basically, the severity with which the heat of the part in the middle is transmitted. The cooling means have different severities quenching, including not only (as can be seen in Table 3) but also in terms of its temperature and velocity.

Table III.
Tempering comparative severity of different cooling mediums depending on the temperature of the medium at ^{0}C and the average velocity in m / s.

Cooling media	TEMPERATURE OF COOLNG MEDIA (^{0}C)	CIRCULATION VELOCITY m / s	SEVERITY
WATER	32	0 O,25 0,51 0,76	1,1 2,1 2,7 2,8
	55	0 0,25 0,51 0,76	0,2 0,6 1,5 2,4
OIL	60	0 0,25 0,51 0,76	0,5 1,0 1,1 1,5

From the table it can be seen that the water has a higher severity than oil quenching; and that as the velocity increases the severity of cooling, both the water and oil increases.

There are different types of oil cooling. Table 3 shows the water with rapid compared oils, which are double or triple tempering severity compared with conventional.

Also recommend using cooling oil, which is calculated to 60-70 ° C [3] .

Moreover, the cooling rate of the different media also depends on the temperature range in which it occurs. This can be seen in Table 4 [2] .

Table IV.
Cooling rate in different mediums depending on the temperature range during cooling.

MEDIO DE ENFRIAMIENTO	VELOCIDAD DE ENFRIAMIENTO EN ^{0}C / s	
	RANGO 650-500 ^{0}C	RANGO 300-200 ^{0}C
Agua a 30 ^{0}C	500	270
Agua a 50 ^{0}C	100	270
Agua a 75 ^{0}C	30	200
Emulsión de aceite en agua	200	-
Aceite mineral promedio	100-150	20-50
Aire comprimido	30	10
Aire tranquilo	3	1

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Thus, considering all the proposed elements, you can obtain a favorable result of the required hardenability.

The procedure of calculation is displayed in cases where is required to differentiate the properties of the core and the surface.

1.2 Treatment Needed In Real Difference Of Centre And Surface [7].

The first aspects to consider in this case are:

a) What properties are required on the surface?
b) What properties are required in the nucleus?
c) How deep layer is needed?
d) Possible stress gradient generated in - core surface.

The first two aspects are data conditions. For calculating the depth of layer in the case of flexural axis can be carried out according to the method shown.

In a coordinate system scale, will be located on the Y axis, dimensions in mm, placing first the radio axis and the X axis MPa these will stack values of different efforts. This scheme will be of the form shown in Fig. 3

In other cases in which contact stresses penetrate deep into the component, to the entire surface layer or even below it (negative gradient), methods are needed to generate thicker surface layers.

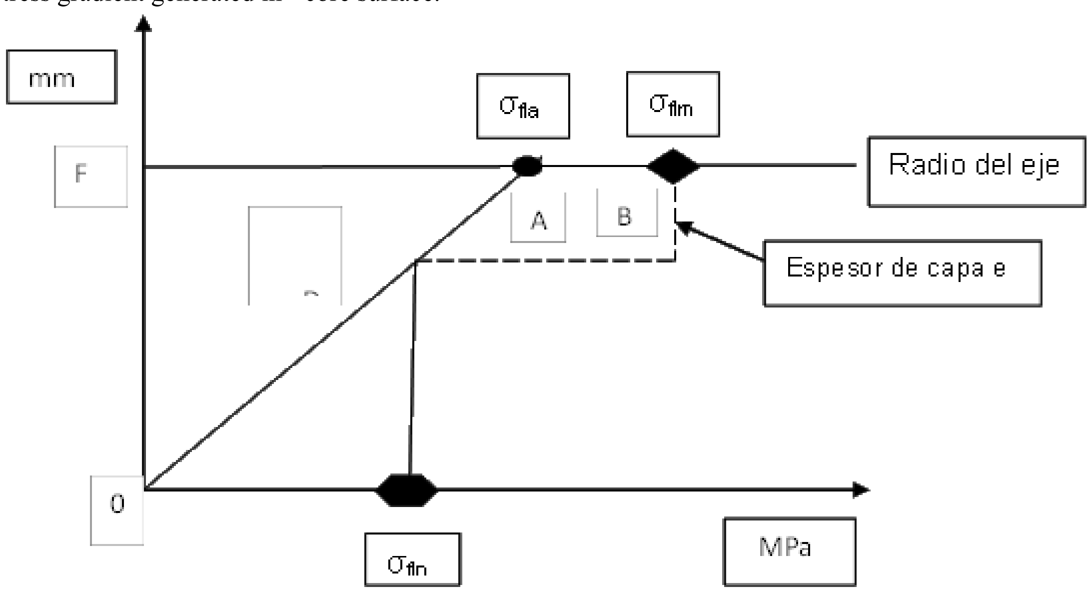

Fig.3 Schematic for calculating the layer thickness depending on the efforts of acting bending.

On the line that demarcates the end of the radius of the shaft the value of the bending stress acting, which we denote by σ_{fla} be placed. Then on the same axis the value of the bending stress of material in surface layer, which we denote as $\sigma_{flm.}$

Naturally, $\sigma_{flm} > \sigma_{fln}$, which, together with the necessary depth layer to obtain, tell us will be located , the value to be obtained in the layer, which in turn delimit, as we shall see later the type of surface treatment to be used.

Then, on line X the value of bending stress required in the core of the material which we denote by σfln will be located. As is known the bending stress applied to a shaft, follow a linear distribution from the surface to the center, so σ_{fla} unite with the origin that is the center axis (See. Fig. 1). He then lifted straight from σ_{fln} to the point D, be known until deep layer must be obtained to provide a comprehensive response to the request of defendants effort, this value is given by σ_{fln} - D.

This way it can set, based on similarity of triangles, a mathematical formula to calculate the layer thickness e.

$$\sigma_{fla} / r = \sigma_{fla} - \sigma_{fln} / e \qquad (3)$$

where:

σ_{fla} the bending stress is applied .

r is the radius of the shaft

σ_{fln} the bending stress that can be supported by the core.

e is the layer thickness to be calculated.

Therefore :

$$e = (\sigma_{fla} - \sigma_{fln})\, r / \sigma_{fla} \qquad (4)$$

Always it is desirable to increase the thickness calculated from 0.1 to 0.15 mm in order to avoid the critical point D.

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Let us now as final aspect, and using the concepts of engineering surface layer, which type of surface should be obtained, which may also establish the need to vary the steel employed, provided they are guaranteed the same conditions set before.

For this analysis should take into account the gradient of efforts that may occur, which is not within the scope of this work.

The wide variety of surface materials engineers that could be used, allows the designer selection, at least to some extent, rather than using equal volumetrically and surface properties of the material [10,11].

Fig. 4 shows the wide range of combination of depth and hardness layer which can be obtained in the surfaces by different technologies [3].

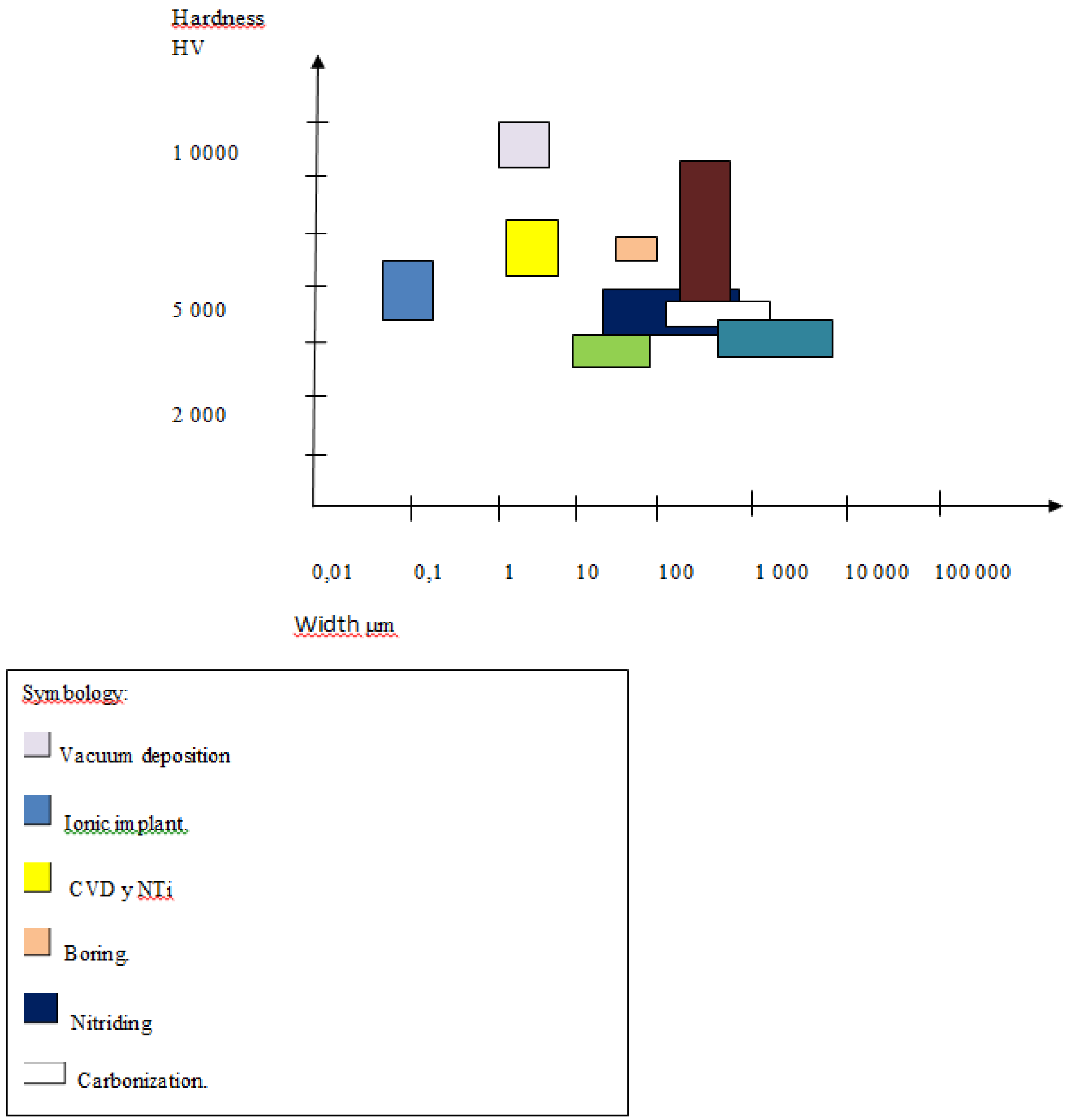

Fig. 4 Typical hardnesses and depths depending on different forms of coatings and surface hardening.

From Figure 4 It can be concluded that different methods provide different possible combinations of depth and hardness of the surface layer. It is noteworthy that some methods such as chemical nickel plating, chrome phosphating and others are missing. Those surface deposition methods like PVD, CVD or ion implantation which produce only very thin layers and high hardness, their use will be useful, in applications with a minimum extent of wear and where the acting surface stress rapidly decreases during work, so that the thin surface layer is removed. This is associated with the elastic interaction stage is reached quickly.

II. Conclusions

In the present work is shown, by an algorithmic reasoning and using various tables and figures, some created by the author, a procedure for the most successful technology selection volumetric treatment of steel parts or those calculation where it is needed to differentiate properties between the core and the surface of some elements of machine steels. In the latter had been introduced the concept of engineering surface for response, not only to the requirements of strength and hardness of the outermost layer of the element, but also the depth of the layer to prevent acting loads that cause damage to the core material, when the layer thickness is insufficient. A figure for calculating the depth of layer in elements subject to bending loads is provided.

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