Improvement of Surface Hardness By Ball Milling Technique for Carbon Steel (CK 45).

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ABSTRACT

This research is devoted to study the effect of ball milling technique to improve the surface hardness of carbon steel (CK 45) die guides. This process depends on a rotating cylinder with number of certain size steel balls. Experimental works are carried out on guides rods with (15 mm) diameter, and (35 mm) length processed on laboratory ball mill. The factors those studied in this process are rotating speed, and time. The surface hardness is recorded before and after the processing. The results show that the best surface hardness is (86.11 Hv) obtained with ball size (5 mm) diameter rotate with (30 rpm) for (90 min.) processing time.

الخلاصة

في هذا البحث استخدمت تقنية طاحونة الكرات المتدحرجة لتحسين الصلادة السطحية لعمود دليل قالب التشكيل من الصلب الكاربوني (CK45). تعتمد هذه العملية على دوران اسطوانه وهي محملة بعدد من الكرات بحجم محدد مصنعة من الصلب. تم إجراء التجارب العملية على أعمدة بقطر (15 mm) وطول (35 mm). وقد تم دراسة العوامل المؤثرة منها سرعة الدوران والزمن. وقد تم قياس وتسجيل قيم الصلادة السطحية قبل العملية وبعدها. وقد أظهرت النتائج بأن أفضل صلادة سطحية هي (86.11 Hv) تم الحصول عليها بإستخدام حجم كرات بقطر مقداره (5 mm) وسرعة دوران للصندوق مقدارها (30 rpm) خلال زمن مقداره (90 min.).

Key words: die guide, surface hardness, ball mill, guide rod.

INTRODUCTION

Stability in engineering structures is an important factor which must be considered to ensure the safe usage of parts against failure , this factor limits the ultimate load permitted before failure occurs, therefore it takes a great important in structural engineering especially dies technologies engineering. The prior studies achieved due to this problem deal for long time with elastic behavior of structure which finally caused failure .The later studies considered the plastic behavior of structural materials. In both cases the deflected part in structure provides a weak point finally causes the failure.

When a column is subjected to increasing compressive load, buckling side-way of the part will occur according to each of the following:

1. The amount of increasing load.
2. Excessive length of column.
3. The properties of materials used.
4. The eccentricity of the applied load.

Therefore, there is a need for tool to improve the buckling resistance to increase the permitted load of materials. This research tries to test a method to increase a critical buckling load for die guide of (CK 45) steel. Ling and Wen (1998)[1] studied the structural strength and crushing behavior of single and bi-material stub columns subjected to dynamic loads. This research studies the local and post buckling behavior of the stiffened and unstuffed end compression elements under dynamic loading conditions with different strain rates. The results showed that the strength of stub columns depends on the material yield strength, the width to thickness ratio and the type of compression element, and the strain rate used in the test. Wang &Cao (1999)[2] has studied the buckling in sheet metal forming , prediction and prevention of side – wall wrinkling are extremely important in the design of tooling and process parameters in sheet metal forming processes. Arif & Urel (2005)[3] has studied the buckling analysis of slender prismatic columns with a single non propagation open edge crack subjected to axial loads has been presented ,he found that a crack located in the section of maximum bending moments causes the largest decrease in the buckling loads. Also Al – Jubori (2005)[4] has showed that compression buckling stresses under static loading are higher than those under dynamic loading . Van & S. Pei (2006)[5] has studied the buckling reliability of deteriorating steel beam ends. The results of a study whose objective was to develop reliability charts for buckling of deteriorated steel beam ends based on state of the art measured truck load statistical modeling procedures was presented. Saha& Banu (2007) [6] presented a method of identifying the buckling load of a beam column based on a technique named multi – segment integration technique. This method has been applied to a number of problems to a certain its soundness andaccuracy. They consider a boundary value problem for the beam column equation. Shengbin et. al (1998)[7] dealt with the elastoplastic large deformation analysis of short cylinders subjected to compression and bending. In the analysis, a type of four– node doubly curved shell element was employed .Both the initial deflections and residual stresses were taken into consideration. Barbero (1999)[8] studied the pultruded structural shapes as columns of intermediate length for which the global and local buckling loads are close. Interaction between the two buckling modes is accounted design by an empirical interaction constant. Theoretical / numerical prediction of such constant presented in this paper. Juhas (2003)[9] presents a fundamental information about realized experimental and theoretical research and introduces a new calculation conception for determination of the buckling load – carrying capacity for compressed steel elements with hybrid cross sections. Hilton (2006)[10] studied the dynamic response of linear viscoelastic temperature dependent prismatic columns under axial compressive loads and due to thermal stresses and moments .Creep buckling instabilities and probabilities of material failures are analyzed to determine column life or survival times. Optimal designer materials are studied to minimize thermal stress and axial load effects while concurrently lowering failure probabilities and extending survival times. Oihoff & Seyranian (2008)[11] developed a mathematical formulation of column optimization problems allowing for bimodal optimum buckling loads. The columns are continuous and linearly elastic, and assumed to have no geometrical imperfections.

The method of ball milling technique is a cold work process. In this process the work piece surface is impacted repeatedly with a number of cast steel balls, at a high velocity which make overlapping indentation on the surface causing a slight plastic flow and stretching of the surface metal to depth of a few hundredths of a millimeter using ball sizes that range from (0.125-5) mm in diameter. The stretching of the outer fibers is resisted by those underneath, which tend to return them to the original length, thus producing an outer layers having a compressive stress while the below are in tension .This action causes improving the mechanical properties of the work piece by increasing the surface hardness which is important to withstand failure due to buckling or even breaking. In addition to increase the stress corrosion resistance, reducing porosity in non – ferrous castings, improving surface wear ability as on gear teeth, improves the oil retentively of same surfaces [3].

EXPERIMENTAL WORK

The ball mill tests are achieved on a machine as shown in **figure (1)**. The internal shape of the container is hexagonal. Due to the rotating an impact action will be generated. The working factors such as drum velocity, time of processing and balls size can be controlled. The size of balls is fixed on (5 mm) .The guide rods diameter is (15 mm) as shown in **figure (2)**. Two sets of tests are achieved as follows:

1- 1st. set includes variable rotary speeds 20, 25, and 30 rpm. With processing time of 30 minutes.
2- 2nd. Set includes variable processing times 30, 60, 90 minutes with rotary speed of 30 rpm.

Figure (3) shows the microscope which is used for measuring the microstructure of tested rods as shown in **figure (4)**. **Tables (1 & 2)** show the mechanical properties and chemical analysis of (CK45) respectively, and **table (3)** shows the experimental tests factors (drum speed and processing time).

Vickers Hardness Testing:

Before and after the processing the specimens are tested for surface hardness and the depth that is affected by this treatment as shown in **table (4)** by using Vickers hardness tester with (250 gram) load as shown in **figure (6)**.

RESULTS AND DISCUSSION

Table (3) represents the measured surface hardness before and after the 1st. set of experiments which includes the variable rotary speed with (5 mm) diameter balls and a processing time 30 min., while **table (4)** shows the results of surface hardness with the same ball size and a fixed drum speed of (30 rpm) at a variable times (30, 60 and 90 min.).The die guides normally represent essential components in production dies. The job of these guides is to maintain the movement of the punch in the center line towards the die opening. To avoid failure (bending or probably breaking) of guide within pressing operation, the guides must be selected as a steel metal with a sufficient surface hardness , so this research tries to use a balls indenting cold working process to attain a sufficient guide surface hardness. There are many methods used for developing this parts as mentioned in prior researches. In this research the plastic work that can be achieved by balls attack on the surface grain structure of steel rod due to compression action of indentation of the balls on the surface. These changes in the grains shape shall generate a strain hardening and as a result causes increasing surface hardness. The thickness of affected layer gradually decreased as depth increased **figure (4)** shows the layer thickness that is affected by balls attack. **Table (2)** shows the hardness values changes which are decreased as the depth increased, and the results also show that the hardness is returned back to the as received rod hardness in the depth of (600 micron) that is means the hardness layer thickness is equal to (400 micron). The results which obtained from the tests showed that the surface hardness is developed generally and they referred to that the surface hardness is direct proportional with both the drum speed and processing times with fixed other factors as shown in **figures (7 & 8)**, and the best hardness number is obtained with (30 rpm) drum speed and (90 min.) processing time which is equal to (86.11 Hv).

CONCLUSION

The increasing of surface hardness by balls indenting cold working method which is achieved on CK45 die guides gave good results so this process may be considered as a developing tool in surface hardening fields.

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Table (1): The mechanical properties of (CK45) [12]

Material	Yield stress MPa	Ultimate strength MPa	Elongation (%)	Modulus of elasticity GPa.
CK45(DIN)	355	590-710	≥18	205

Table (2): The chemical analysis of (CK45)

Steel	Carbon %	Manganese %	Silicon %	Silver %	Phosphor %
Standard (DIN)	0.42-0.50	0.50-0.80	≤0.40	≤0.030	0.035
Experimental	0.453	0.570	0.4	0.027	0.034

Table (3): Represents the results experiments factors

Sample	Drum speed (rpm)	Processing time min.
S1	20	30
S2	25	30
S3	30	30
S4	30	30
S5	30	60
S6	30	90

Table (4): Vickers micro hardness numbers with a load of 0.25 Kg.*

Samples	Hv at		
	200 μmm	400 μmm	600 μmm
S1	79.14	79.00	78.13
S2	82.67	80.50	78.15
S3	83.22	81.40	78.13
S4	83.22	81.26	78.14
S5	84.13	82.00	78.92
S6	86.11	83.21	79.10

*Hv = 78.12 before hardening.

Figure (1): Represents the ball mill equipment that is used in the process, (a) the hexagonal drum, (b) the electrical motor, (c) the gear box, (d) is the structural frame.

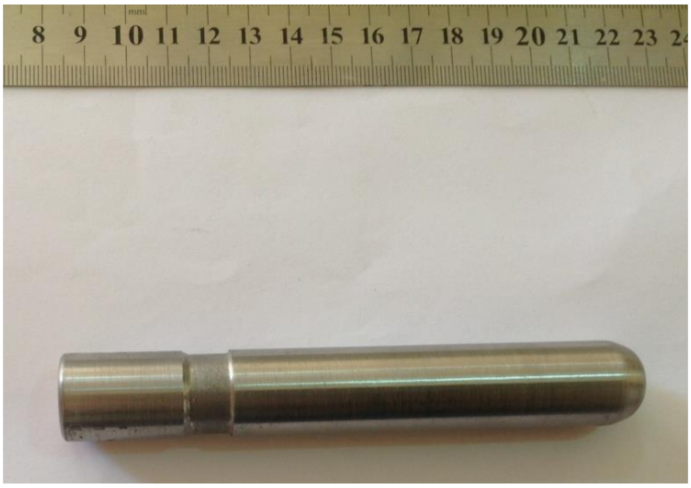

Figure (2): Represents the tested rod that is used in the test,

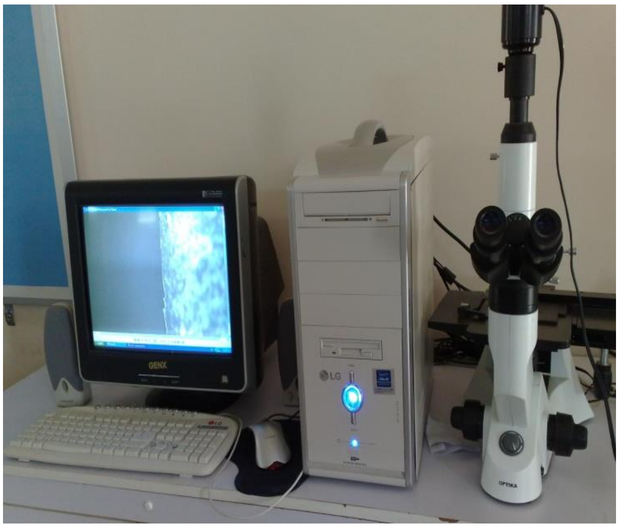

Figure (3): OPTIKA E Plan (40×0.65) microscope that is used in the testing.

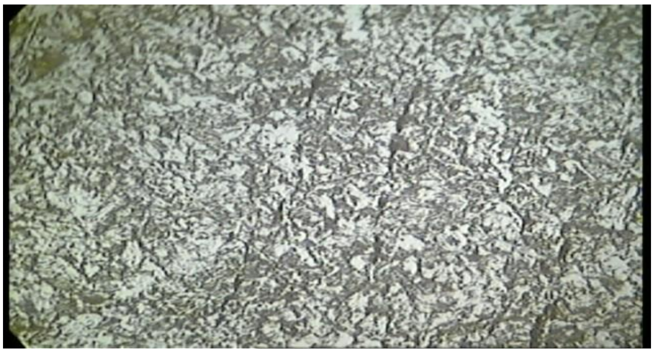

Figure (4): shows the non- hardened microstructure of this alloy.(400x)

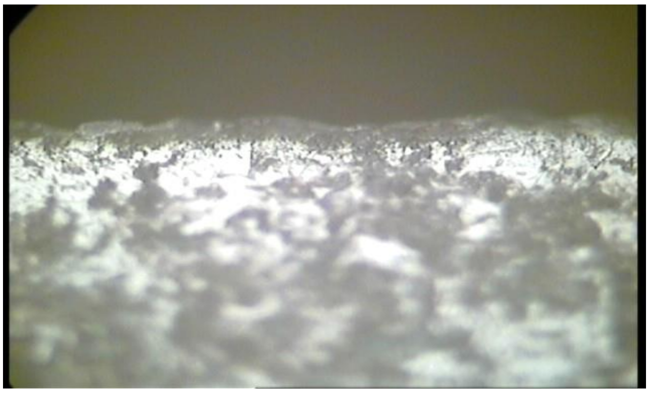

Figure (5): shows the hardened microstructure of (CK45), (x500).

Figure (6): Vickers hardness tester,

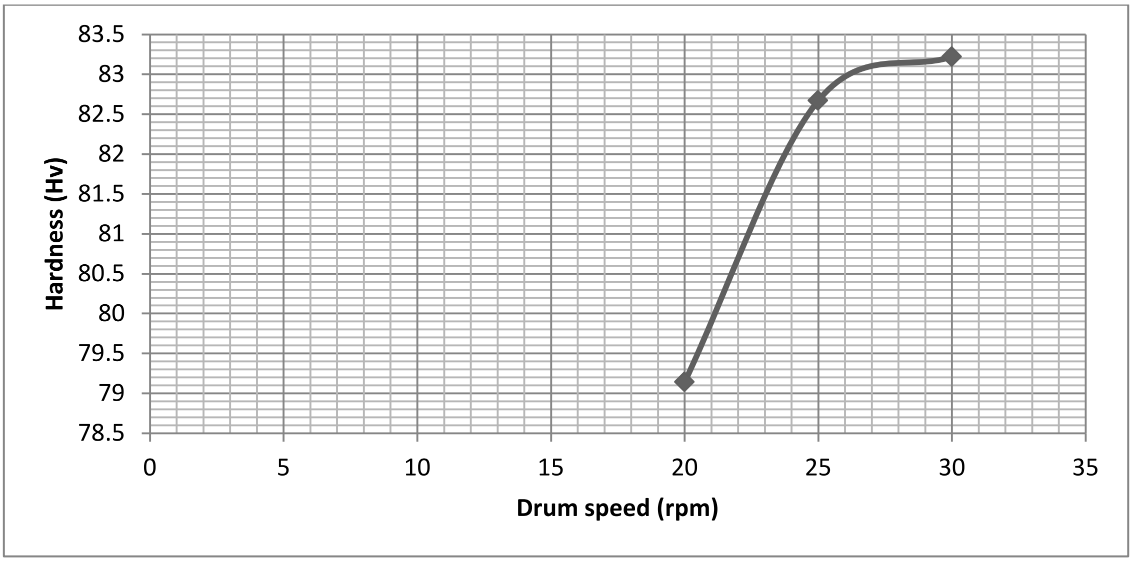

Figure (7): The relation between surface hardness of guide and drum speed.

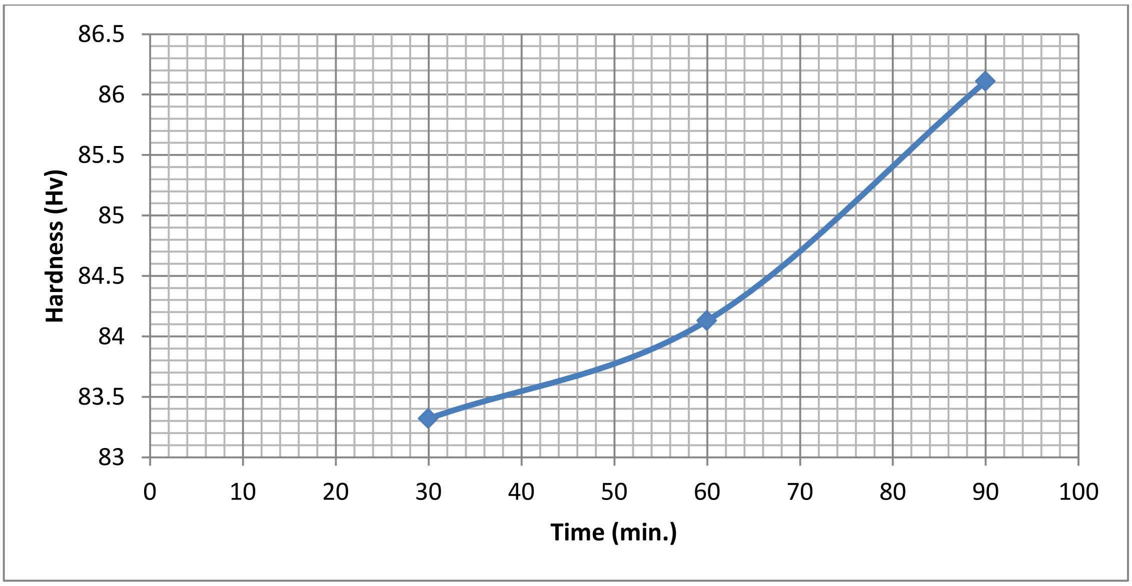

Figure (8): The relation between surface hardness of guide and processing time.