ISSN 2286-4822
www.euacademic.org

EUROPEAN ACADEMIC RESEARCH
Vol. VIII, Issue 3/ June 2020

Impact Factor: 3.4546 (UIF)
DRJI Value: 5.9 (B+)

Changes in mechanical properties of steel 42 CrMo4 with manganese addition (Part A)

FATIMA HOMEIDA
FATIMA KAREEMALDEEN
MUSAB HAJALFADUL
ELJACK BABIKER
Faculty of Engineering, University of Khartoum
Khartoum, Sudan

Abstract

This study is aiming to study the effect of adding the manganese as an alloying element to the alloy steel. Such effects shall provide a great variations and flexibility in making different types and grades of alloy steel. Hence this paper will be rich in providing and having many options in engineering materials to cover the needs of engineers. The most mechanical tests are Tensile and Compression. Mechanical tests are conducted and discussed in detail in this work. From tensile tests it was noticed that the ultimate tensile strength and yield strength increased when the mass percentage of manganese increased. Also, it was found that the specimen that contains high concentration of manganese, has high tensile strength and yield strength and vice versa.

Keywords: Steel alloys, Manganese alloys, Mechanical properties

INTRODUCTION

The primary concern of engineers when selecting a material is to match the mechanical properties with the service requirements of the component. Knowing the conditions of load and environment under which the component must operate, engineers must then select an appropriate material, using tabulated test data as the primary guide.

They must know what properties they want to consider, how these are determined, and what restrictions or limitations should be placed on their application. Only by having a familiarity with test procedures, capabilities, and limitations can engineers determine whether the listed values of specific properties are, or are not, directly applicable to the problem at hand and then use them intelligently to select a material.

Perhaps the most common classification that is encountered in engineering materials is whether the material is metallic or non-metallic [1]. The common metallic materials are such metals as iron, copper, aluminum, magnesium, nickel, titanium, lead, tin, and zinc and the alloys of these metals, such as steel, brass, and bronze. They possess the metallic properties of luster, high thermal conductivity, and high electrical conductivity.

For most manufacturing applications, however, metals are not used in their pure form, but in the form of alloy materials composite of two or more elements, at least one of each is a metal. The addition of the second element to form an alloy usually results in a change of properties. Knowledge of alloys and their properties is important to intelligent selection of materials for given applications.

Properties of material are classified into physical, chemical, and mechanical properties. This research is focusing on mechanical properties. Mechanical properties describe how a material will response to applied load or force, which is the dominant factor in material selection. These mechanical properties are determined by subjecting prepared specimens to standard laboratory tests designed to evaluatethe material reaction to applied force. Common mechanical testes are tensile [2-4], compression [5,6], impact [7-10], and hardness [11-13].

Steels are iron-carbon alloys that may contain appreciable concentrations of other alloy elements, there are thousands of alloys that have different compositions and/or heat treatment. The mechanical properties are sensitive to the content of carbon, which is normally less than 1.0 wt %. Some steels are classified according to carbon concentration, namely, into low-medium, and high-carbon types. Subclasses also exist within each group according to the concentration of other alloying elements.

Mechanical properties

Many materials, when in service, are subjected to forces or loads; examples include the aluminum alloy and composites from which an airplane wing is constructed [14-16]. In such situations it is necessary to know the characteristics of the material and to design the member from which it is made such that any resulting deformation will not be excessive, and fracture will not occur.

The mechanical behavior of a material reflects the relationship between its response or deformation to an applied load or force [17,18]. Important mechanical properties are strength, hardness, ductility, and stiffness. The mechanical properties of materials are ascertained by performing carefully designed laboratory experiments that replicate as nearly as possible the service conditions. Factors to be considered include the nature of the applied load and its duration, as well as the environmental condition.

It is possible for the load to be tensile, compressive, or shear, and its magnitude may be constant with time, or it may fluctuate continuously. Application time may be only a fraction of a second, or it may extend over a period of many years. Service temperature may be an important factor. Mechanical properties are of concern to a variety of parties (e.g., producers and consumers of materials, research organizations, and government agencies) that have differing interests.

Tensile test:

One of the most common mechanical stress–strain tests is performed in tension. As will be seen, the tension test can be used to ascertain several mechanical properties of materials that are important in design. A specimen is deformed, usually to fracture, with a gradually increasing tensile load that is applied axially along the long axis of a specimen.

The output of such a tensile test is recorded on a strip chart (or by a computer) as load or force versus elongation. These load–deformation characteristics are dependent on the specimen size. For example, it will require twice the load to produce the same elongation if the cross-sectional area of the specimen is doubled. To minimize these geometrical factors, load and elongation are normalized to the respective parameters of engineering stress and engineering strain.

Stress is defined by the relationship

$$\boldsymbol{\sigma = \frac{F}{A_o}}$$

in which F is the instantaneous load applied perpendicular to the specimen cross section, in units of newton (N) or pounds force (lbf), and A_o is the original cross-sectional area before any load is applied (m^2 or in.^{2}). The units of engineering stress (referred to subsequently as stress) are megapascals, MPa (SI) (where 1 MPa 10^6 N/m2), and pounds force per square inch, psi (Customary U.S.). Engineering strain is defined according to

$$\boldsymbol{\varepsilon = \frac{I_i - I_o}{I_o} = \frac{\Delta I}{I_o}}$$

In which l_0 is the original length before any load is applied, and l_i is the instantaneous length. Sometimes the quantity (l_i - l_0) is denoted as (Δl) and is the deformation elongation or change in length at some instant, as referenced to the original length. Engineering strain (subsequently called just strain) is unit less, but meters per meter or inches per inch are often used; the value of strain is obviously independent of the unit system. Sometimes strain is also expressed as a percentage, in which the strain value is multiplied by 100.

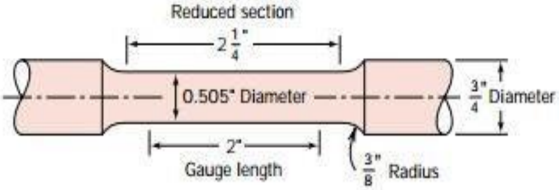

Figure 1: A standard tensile specimen with circular cross section

Compression test

A compression test is conducted in a manner similar to the tensile test, except that the force is compressive and the specimen contracts along the direction of the stress. Equations 7.1 and 7.2 are utilized to compute compressive stress and strain, respectively. By convention, a compressive force is taken to be negative, which yields a negative stress. Furthermore, since l0 is greater than li, compressive strains computed from Equation 7.2 are necessarily also negative. Tensile tests are more common because they are easier to perform; also, for most materials used in structural applications, very little additional information is obtained from compressive tests.

Compressive tests are used when a material's behavior under large and permanent (i.e., plastic) strains is desired, as in manufacturing applications, or when the material is brittle in

Steel 42 CrMo4 Sample specifications

General properties: CrMo-alloyed steel, engineering steel supplied in tempered and quenched conditions. Good machinability.

Applications: Components with high requirements on toughness, e.g. gear wheel, pinions, connecting rods, parts for mechanical engineering.

Conditions of delivery: quenched tempered.

Chemical composition: Contain C, Si, Mn, Cr, Mo, Ni, Al, Cu, Ti, V, Nb, Co, W, Pb and Fe.

Table 1: Sample specification (mechanical properties)

Diameter D (mm)	<16	>16-40	>40-100	>100-160	>160-250
Thickness t (mm)	<8	8<t>20	20<t>60	60<t>100	100<t>160
Yield strength Re (N/mm2)	Min.900	Min.750	Min.650	Min.550	Min.500
Tensile strength Rm (N/mm2)	1100-1300	1000-1200	900-1100	800-950	750-900
Elongation (%)	Min.10	Min. 11	Min.12	Min. 13	Min.14
Reduction of area (%)	Min.40	Min.45	Min.50	Min.50	Min.55
Toughness J	Min.30	Min.35	Min.35	Min.35	Min.35

Preparations for testing

For the chemical composition test, the sample was cleaned from impurities beforehand and then the chemical composition test was performed. For hardness test, the sample was cleaned to obtain more accurate properties. For tensile test, the sample was cut and formed to suitable shape in order to be fixed.

Chemical composition test

By using a spectrometer, which absorbs different wavelengths of light at different intensities, the light that passed through the sample was analyzed [19]. Each element has its own unique wavelength that indicates the elements contained in a sample.

Tensile test:

Tensile testing is a fundamental materials science and engineering test, in which a sample is subjected to controlled tension until failure. Properties that are directly measured from the tensile test are ultimate tensile strength, yield strength and ductility.

Tensile test procedures

- Before testing, the diameter of the test piece was measured, and the cross-sectional area was determined using a gauge.
- The test piece was gripped in the jaws of the test machine, ensuring that the test piece was held in such a way that force applied was axial.
- The writing device was prepared for plotting the stress-strain diagram.
- Load was applied by an already determined rate of stress.
- After fracture, the maximum force was noted, the final gauge length and minimum diameter were measured. The force at the point of yield was found from stress strain diagram.
- After fracture, the tensile strength, yield strength, elongation percentage were determined.

RESULTS AND ANALYSIS

Results of chemical composition tests:

Table 2: chemical composition of steel 42CrMo4 Specimen

	C%	Si%	Mn%	Cr%	Mo%	Ni%	Al %	Cu%	Ti%	V%	Nb%	Co%	W%	Pb%	Fe%
1	0.425	0.280	0.342	1.285	0.186	0.0	0.002	0.112	0.00	0.00	0.001	0.037	0.054	0.005	97.270
2	0.468	0.305	0.545	0.989	0.107	0.00	0.003	0.132	0.00	0.00	0.001	0.037	0.250	0.005	97.159
3	0.469	0.261	0.689	1.166	0.138	0.0	0.012	0.112	0.0.	0.00	0.001	0.038	0.147	0.006	96.961

Tensile test:

Yield stress and tensile strength results were as follows:

Table 3: yield and tensile strength of specimen

Specimen number	Mn%	Ultimate tensile strength	Yield strength
1	0.342	1100	900
2	0.545	1200	950
3	0.689	1250	970

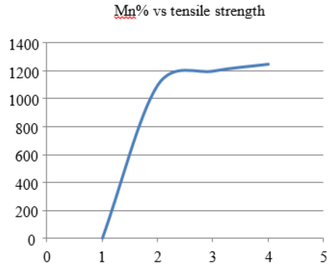

Figure 2: Mn% vs tensile strength of specimen

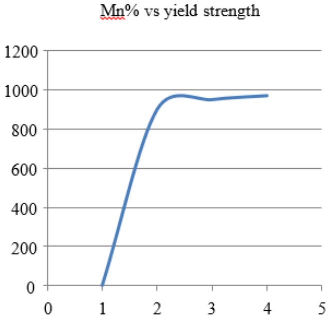

Figure 3: Mn% vs yield strength of specimen

CONCLUSION

- From tensile tests it was noticed that the ultimate tensile strength and yield strength increased when the mass percentage of manganese increased.
- The specimen that contains high concentration of manganese, has high tensile strength and yield strength and vice versa.
- From this research it was found that heat treatment should be applied to obtain good results.
- When chromium is added to carbon steel that has a good percentage of manganese, this negatively affected its hardness properties.

REFERENCES

1. Ross, Robert B. Metallic materials specification handbook. Springer Science & Business Media, 2013.
2. Guo, H., et al. "Tensile ductility and necking of metallic glass." Nature materials 6.10 (2007): 735-739.
3. Stoica, M., et al. "Strain distribution in Zr 64.13 Cu 15.75 Ni 10.12 Al 10 bulk metallic glass investigated by in situ tensile tests under synchrotron radiation." Journal of Applied Physics 104.1 (2008): 013522.
4. Yang, B., et al. "In-situ thermographic observation of mechanical damage in bulk-metallic glasses during fatigue and tensile experiments." Intermetallics 12.10-11 (2004): 1265-1274.
5. Song, Hong-Wei, et al. "Fracture mechanisms and size effects of brittle metallic foams: In situ compression tests inside SEM." Composites Science and Technology 68.12 (2008): 2441-2450.
6. Dubach, A., et al. "Micropillar compression studies on a bulk metallic glass in different structural states." Scripta Materialia 60.7 (2009): 567-570.
7. Elamin, Mohammed, Bing Li, and K. T. Tan. "Impact damage of composite sandwich structures in arctic condition." Composite Structures 192 (2018): 422-433.
8. Khan, M. H., et al. "X-ray micro-computed tomography analysis of impact damage morphology in composite sandwich structures due to cold temperature arctic condition." Journal of Composite Materials 52.25 (2018): 3509-3522.
9. Elamin, M., B. Li, and K. T. Tan. "Impact Performance of Stitched and Unstitched Composites in Extreme Low Temperature Arctic Conditions." Journal of Dynamic Behavior of Materials 4.3 (2018): 317-327.
10. Tan, Kt, Mohammed Elamin, and Bing Li. "Impact Performance and Damage Behavior of Composite Sandwich Structures in Arctic Condition." Proceedings of the American Society for Composites—Thirty-second Technical Conference. 2017.
11. Herrmann, Konrad, ed. Hardness testing: principles and applications. ASM international, 2011.
12. Chandler, Harry, ed. Hardness testing. ASM international, 1999.
13. Clinton, D. J., and R. Morrell. "Hardness testing of ceramic materials." Materials chemistry and physics 17.5 (1987): 461-473.
14. Elamin, M., and J. Varga. "Plate impact method for shock physics testing." Material Sci & Eng 4.1 (2020): 31-35.
15. Nakai, Manabu, and Takehiko Eto. "New aspect of development of high strength aluminum alloys for aerospace applications." Materials Science and Engineering: A 285.1-2 (2000): 62-68.

16. Huda, Zainul, Nur Iskandar Taib, and Tuan Zaharinie. "Characterization of 2024-T3: an aerospace aluminum alloy." Materials Chemistry and Physics 113.2-3 (2009): 515-517.

17. Elamin, Mohammed, Bing Li, and K. T. Tan. "Effect of Low Temperature on Impact Behavior of Composite Sandwich Structures."

18. Mohammed, Mohammed. "Impact and Post Impact Response of Composite Sandwich Structures in Arctic Condition" Electronic Thesis or Dissertation. University of Akron, 2018. OhioLINK Electronic Theses and Dissertations Center. 17 Jun 2020.

19. Straniero, Oscar, et al. "The chemical composition of white dwarfs as a test of convective efficiency during core helium burning." The Asrophysical Journal 583.2 (2003): 878.