Heat Treatment Analysis of Missile Locking Pin by Numerical Method

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***Abstract*—The aim of this study was to propose heat treatment design process and simulation of missile locking pin made from AISI4340 steel. Austenitisation, quencing and tempering operations were analyzed by commercial metal forming and heat treatment simulation software (FORGE NxT 1.0) to estimate hardness and metallurgical phase of workpiece. From this work locking pin was designed, simulated and prototyped. The results of hardness and tensile test shown that the designed process with simulated results have been resemble.**

Keywords—missile locking pin; AISI4340; heat treatment simulation

I. INTRODUCTION

AISI 4340 steel is a well-known low-alloy commercial steel. Because it can contribute strength, ductility and toughness simultaneously caused by martensitic formation. The chemical composition of AISI 4340 is shown in table 1.

TABLE I. AISI4340 STEEL CHEMICAL COMPOSITION (WT%)

C	Ni	Cr	Mn	Si	Mo	P	S
0.39	1.46	0.67	0.61	0.24	0.17	0.021	0.006

However, it contains some disadvantage on temper embrittlement within a specific range of tempering temperature. In order to identify this range an investigation on microstructure and mechanical properties after performs heat treatment becomes necessary [1].

A raw material AISI4340 with normalized heat treatment condition in this study have a tensile yield strength and ultimate tensile strength of 861 MPa and 1200 MPa respectively, and Vickers's hardness of 282.3 HV. From the calculation and FEM analysis shown the results of yield strength requirement for missile locking pin is approximately 1,400 MPa with a diameter of (cross-section) 10 mm. From this data the heat treatment process must be designed specifically to improve hardness.

In this research, the hardness and metallurgical phase after heat treatment was predicted by numerical method and investigated by experiment in order to perform the corresponding between numerical analysis and experiment.

II. METHODS AND MATERIAL

A. Estimation of a TTT diagram

The pre-processor of Forge software contains a tool that can construct a TTT diagram from a grain size and chemical composition of the material. The algorithm used is based, like so many other transformation kinetics prediction tools [1-3], on the Åkerström and Kirkaldy method [4-5].

First of all, we estimate the characteristic temperatures of phase changes that are the temperatures A_{C1} and A_{C3} (start and end temperatures of austenitization at equilibrium), Hultgren TH temperature, the bainitic transformation start temperature B_S, and the martensitic transformation start temperature M_S. The rules used for computing these temperatures are empirical, established based on a fair amount of nuance contained in a certain domain of validity specified by the author (generally low-carbon low-alloy steels).

Starting by considering the highest temperature: A_{C3}. Because the choice of models and the results they produce are quite varied in the literature, Forge software uses two different rules and establishes an average for these two results. The two models selected are those of Andrews [6] and Kasatkin [7]:

Andrews:

$$A_{C3} = 910 - 203\sqrt{C} - 15.2Ni + 44.7Si + 104V + 31.5Mo + 13.1W - 30Mn - 11Cr - 20Cu + 700P + 400Al + 120As + 400Ti \quad (\%\text{mass}) \quad (1)$$

Kasatkin :

$$A_{C3} = 912 - 370C - 27.4Mn - 27.3Si - 6.35Cr - 37.2Ni + 95.2V + 190Ti + 72Al + 64.5Nb + 5.57W + 332S + 276P + 485N - 900B + 16.2C.Mn + 32.3C.Si + 15.4C.Cr + 48C.Ni + 4.32Si.Cr - 17.3Si.Mo - 18.6Si.Ni + 4.8Mn.Ni + 40.5Mo.V + 174C^2 + 2.46Mn^2 - 6.86Si^2 + 0.322Cr^2 + 9.9Mo^2 + 1.24Ni^2 - 60.2V^2 \quad (\%\text{mass})$$

The austenitization start temperature A_{C1} is not very sensitive to the concentration of carbon and the few models in the literature give pretty much the same results within the scope of low alloy steels [8]. Therefore, we choose just one model; this will be the Andrews model.

Andrews:

$$A_{C1} = 723 - 10.7Mn - 16.9Ni + 29.1Si + 16.9Cr + 6.38W + 290As \ (\%\text{mass}) \quad (2)$$