

Development and Financial Analysis for the Elaboration Jominy Test Device: Conception of an Engineering Project from the Point of View Undergraduate Students

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Abstract— The proposal of the Jominy test is to analyze the hardness of certain specimens, leading to a better understanding of the heat treatments, more precisely, in the severity of the hardening heat treatment, thus contributing to the economy of finite material resources. The project is aligned with the objectives of performing this quantitative and qualitative analysis in the Jominy test project developed by undergraduate students in mechanical engineering, intended from the egress in particular as to skills and performance, in a multidisciplinary way, group work, context, design and diagnosis. The focus is to develop the knowledge about tempering, CCT curves, structure of steels and alloys, constituents such as martensite, austenite, among others, besides the application of the concepts involved in all disciplines of the semester, thus elaborating, step by step, the ideal device for Jominy tests. The main objective is to carry out a study on types of steels, heat treatments and their characteristics, constituents, tests, in order to aggregate knowledge and skills so that we can design the construction of a device for Jominy temperability tests.

Keywords— Tempering, Jominy Test, Martensite, Education, Steel Alloy, SAE 1040, SAE 4140 .

I. INTRODUCTION

Steel is a metallic alloy formed essentially by iron and carbon, with its carbon content varying between 0.008 and 2.11%. It is distinguished from cast iron, which is also an alloy of iron and carbon, but with carbon content ranging between 2.11% and 6.67%. The fundamental difference between the two is that steel, due to its ductility, is easily deformed by forging, rolling and extrusion, while a piece of cast iron is manufactured by the casting process.

At the present stage of society's development, it is impossible to imagine the world without the use of steel.

Steel production is a strong indicator of a country's stage of economic development [1].

It is an extremely important component for the whole economic cycle due to the junction of several productive means. In February of 2020, Brazilian steel companies produced approximately 5.69 thousand tons of metal.

Steel can be fully reused as its properties are maintained during the recycling process. The use of scrap also reduces the iron ore expenses of the mills and reduces the use of natural resources such as coal [2].

The mechanical properties and in-service performance of a metal or alloys depend on their chemical composition, crystalline structure, processing history and the heat treatments performed. In a simplified way, heat treatments can be described as controlled heating and cooling cycles (in metallic material) that cause changes in their microstructure and mechanical properties [3].

While low and medium carbon steels are generally used after forging or rolling, high carbon and alloy steels need to undergo heat treatment before application. Annealing, normalizing, tempering, tempering and coalescing are the most common types of heat treatment. The hardening process will be the focus of this edition.

According [4] points out that The concept of hardenability is linked to the hardening capacity of the steel during rapid cooling, i.e. its capacity to form martensite, at a certain depth in a piece, the most commonly used methods to evaluate hardenability are the critical cooling rate, Grossman test and Jominy test. The critical cooling rate corresponds to the lowest rate that can be used for the whole structure to be martensitic, it is a simple method that can be used directly in the CCT (Continuous Cooling Transformation) curve of the steel. There is a difficulty in using this method because the survey of these curves requires sophisticated equipment in addition to specialized personnel in the area. In view of this, the development of simpler tests like Grossman and Jominy was chosen. Grossman's test (a method that consists in the hardening of several specimens of the same material, but with different diameters, submitting them to metallographic analysis and/or hardness tests in order to determine the critical diameter) has some limitations, such as a series of bars with different diameters to determine the critical diameter.

With the intention of achieving greater speed, Jominy showed a trial using a single bar of one inch diameter and four inches long, this bar is austenitized, i.e., it is taken to above its critical temperature (temperature at which the material becomes only the austenitic constituent in its structure), then cooled by a water jet at room temperature.

After being cooled, a ground track is made longitudinally in the sample and its hardness is measured from the cooled end. This work will be focused on the theoretical development of mounting a jominy device, in order to illustrate the ideal way and the precautions taken to carry out the practical mounting of the device. This work aims to carry out a study on types of steels, heat treatments and their characteristics, constituents, tests, and everything that is involved in order to design the theoretical construction of an equipment to carry out tests of temperability Jominy.

II. METHODOLOGY

2.1 Visual Representation

Subsequently, starting the work, it was necessary to create a sketch drawing of the device. For this task, a handwritten draft was made with its dimensions, as shown in Figure 1.

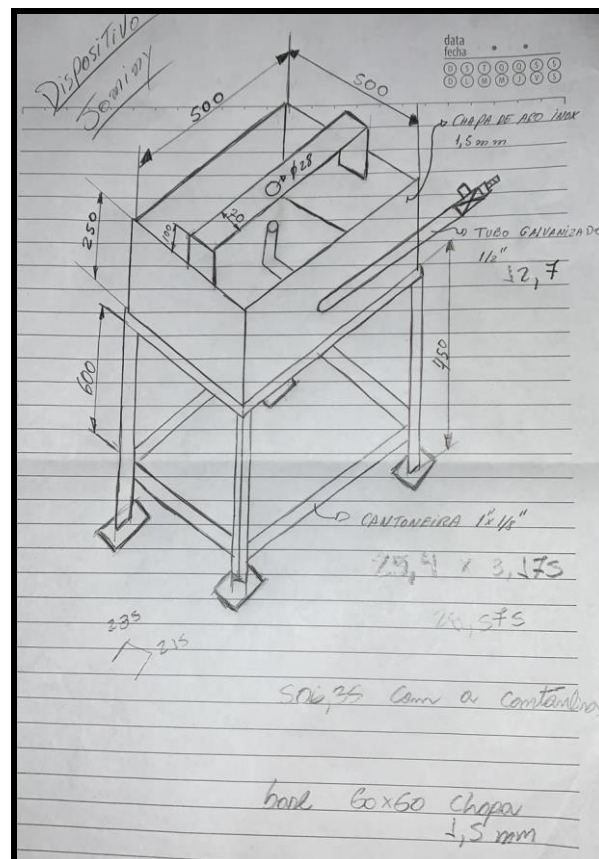


Fig. 1: Scope Device Jominy. Source: Authors (2020)

For the realization of the base we used steel angle bracket of $1" \times 1/8"$, thus making a base and its support according to the sketch, being its total height of 750x600x600mm. And above the base where the cooling process will be carried out with stainless steel plate in its wrapping with a fixation device of the proof body with $\varnothing 28\text{mm}$, and a galvanized tube of $\varnothing 1/2"$ in the inferior part for extraction of the liquid that will be used to cool the proof body.

In order to provide a better visualization, a necessary development of the drawing was determined using the Auto CAD software, being illustrated in Figures 2 and 3.

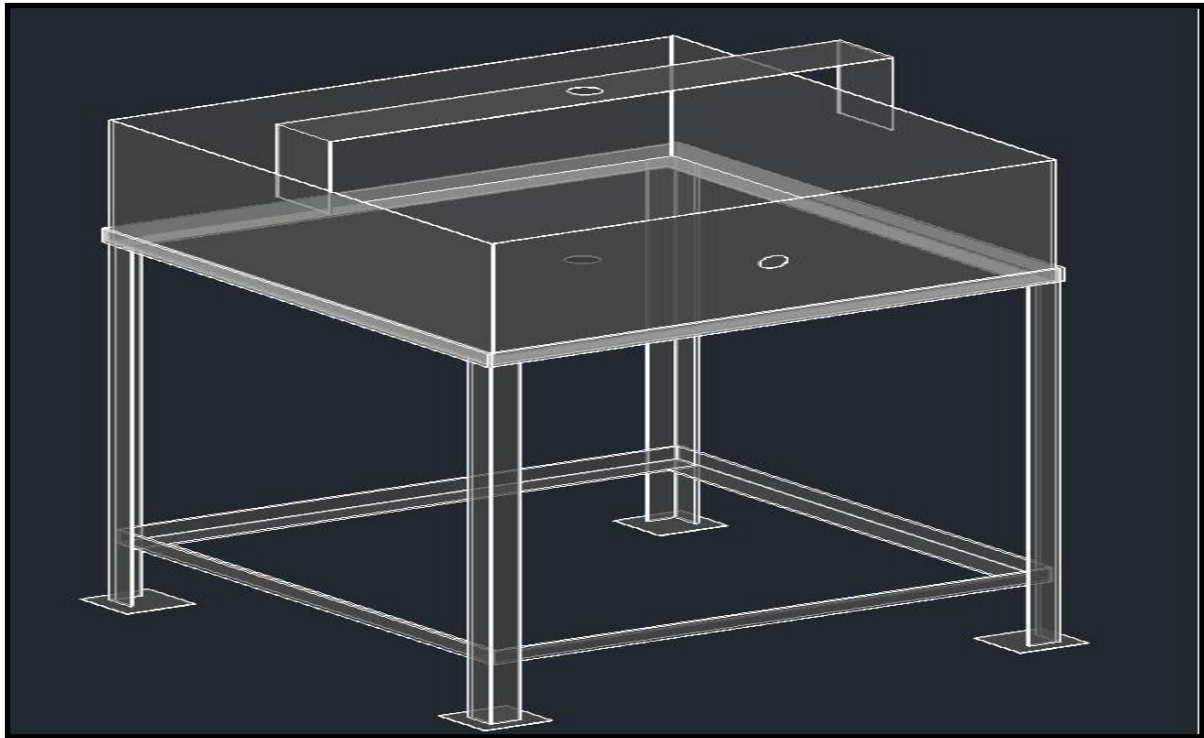


Fig. 2: 2D scope Jominy Device Developed in AutoCad. Source: Authors (2020)

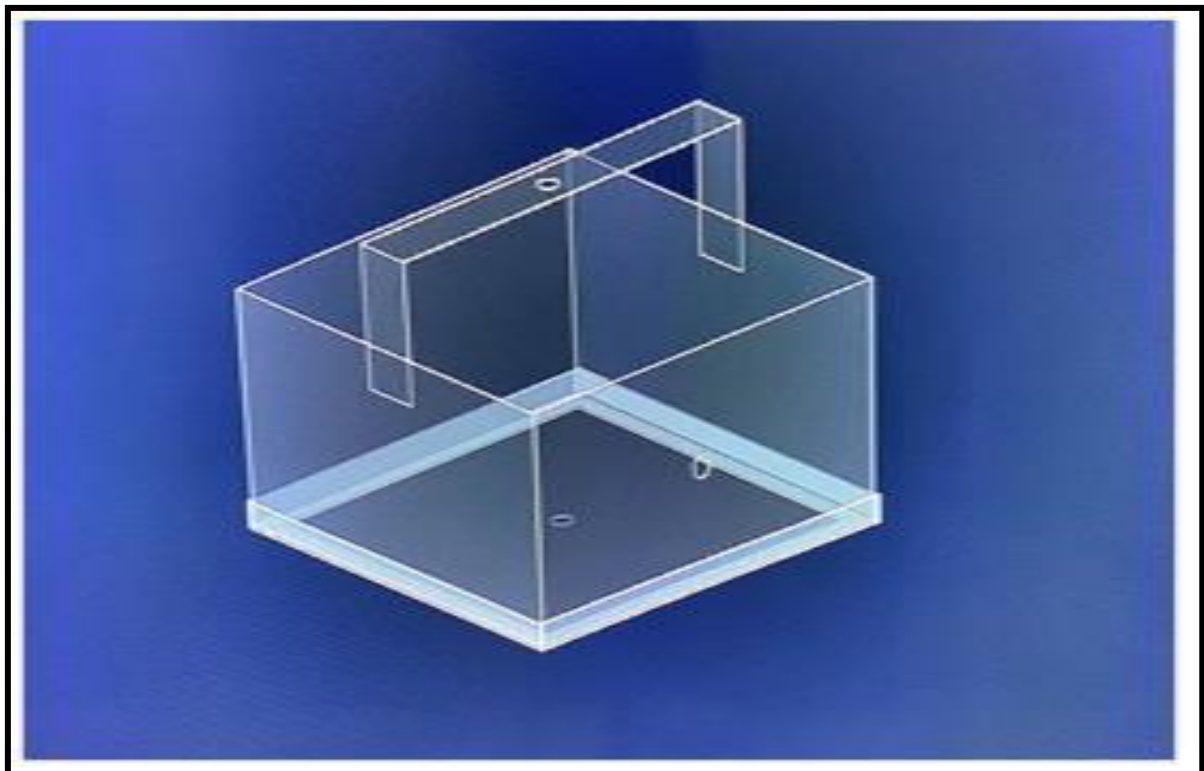


Fig. 3: 3D scope Jominy Device Developed in AutoCad Source: Authors (2020)

According to [5] the CAD (Computer Aided Design) software is framed as graphic tools supported by computer technology, whose objective is the development of drawings and projects applied to the most diverse areas of engineering, architecture, design, industrial design and visual communication, providing commands and environments for graphic representation with a high degree of accuracy static and dynamic, providing visual resources that enable the control of the development process. Because of this, the virtual modeling was of utmost relevance before trying to perform the practical action, reducing the probability of several types of errors, such as inadequate measures, poor grounds, among other possible errors that would cost losses both economically and in relation to time.

Table 1. Costs of the materials. Source: Authors (2020)

Jominy Device Materials List		
Description of the Material	Quantity	Total value
Stainless steel plate model 304 Measure:2000x250x1.5 mm.	1 Part	R\$ 220,00
Stainless steel plate model 304 Measure:600x600x1.5 mm.	1 Part	R\$ 100,00
Stainless steel plate model 304 Measure:1000x150x1.5 mm.	1 Parts	R\$ 50,00
Carbon steel angle bracket Measurements: 1 "x1/8"	6 Meters	R\$ 35,00
Plain carbon steel, thickness 1/4"- Measures 70x70mm.	4 Parts	R\$ 40,00
1/2" full bore ball valve	2 Parts	R\$ 72,00
1/2" BSP galvanized pipe	3 Meters	R\$ 40,00
Galvanized glove 1/2" BSP	2 Parts	R\$ 10,00
Brass Spike 1/2" x Male Thread 1/2" BSP	2 Parts	R\$ 30,00
Elbow 90° Galvanized BSP 1/2"	2 Parts	R\$ 10,00
Carbon steel billet 1040 measures 1.1/4 "x105mm(specimen).	1 Parts	R\$ 20,00
Carbon steel billet 4140 measures 1.1/4 "x105mm(specimen).	1 Parts	R\$ 40,00
Complete	Total	R\$ 667,00

2.2 Cost Survey

A survey of the costs of the materials that will be used was carried out, something extremely relevant for the acquisition of the best possible cost benefit, considering that the available income is limited. After the discussion, the need for the following materials was determined in table 1:

2.3 Selected Materials For Project

Two different types of steels were selected in the hardening process, being SAE 1040 steel and SAE 4140 steel, this was decided to verify the different measures and results between the two, due to their certain TTT curves, TTT curves consists of a diagram that describes what happens with the steel, by means of cooling at different speeds, in several temperatures below 723°centigrade, observing the isothermal transformation of austenite into perlite.

• SAE 1040 Steel Alloy (0.4% C Content)

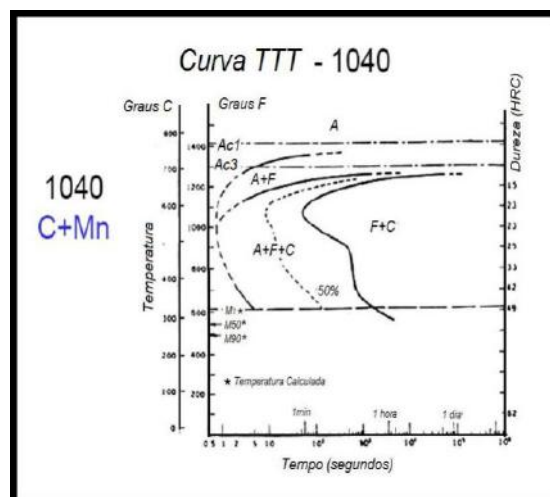


Fig. 4: Curve TTT of Steel Alloy SAE 1040. Source: [8]

This type of steel alloy is normally used in forged parts, distribution bar, connecting rod, shaft, shock absorber rod, brake lever, anchor bolt. It should be noted that SAE 1040 steel alloy has a low carbon percentage, which makes its TTT curve extremely narrow. Thus, there is a complicating factor in obtaining the martensitic constituent, that is, it complicates the treatment of tempering, making it necessary to have a sudden cooling down to less than 1 second to reach 100% martensite. It is important to note that if several tests are made for the same type of steel alloy as 1040, there will be a difference in results, this is due to the size of the grains, inclusions, etc. A 1040 steel

may have, as a rule, its carbon content ranging from 0.37% to 0.44%, which clearly interferes with the final result.

• SAE 4140 Steel Alloy

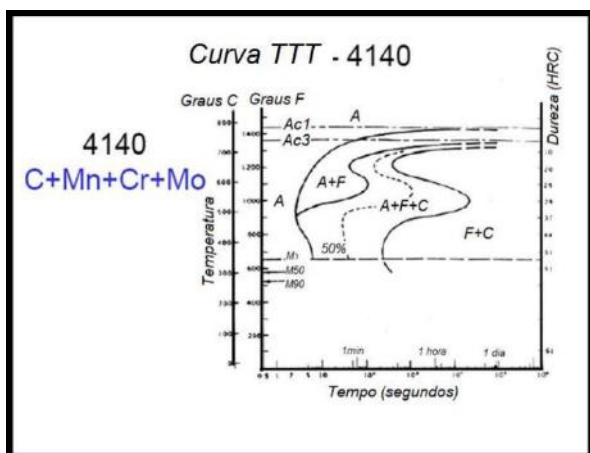


Fig. 5: Curve TTT of Steel Alloy SAE 4140. Source: [8]

SAE 4140 Steel Alloy | Chromium-Molybdenum carbon steel (Villares VL-40 or WNr / DIN 1.7225) is a stronger steel alloy than ordinary carbon steel. Chromium and Molybdenum improve the response of steel to heat treatment tempered and enable greater mechanical resistance [6].

It is a steel alloy for processing with medium temperability, used in the manufacture of different mechanical components, has a good combination of medium mechanical resistance and resistance to fracture and also has high resistance to fatigue.

This material facilitates the test because its curve is not as narrow as that of SAE 1040 steel alloy, this makes it possible to obtain the martensite constituent without the need for more robust or expensive equipment. In this way, we contribute not only to the success of the project, but also in the financial question, saving on equipment and energy.

2.4 Test Bodies

According to [7], in the construction of the Jominy test apparatus, one of the most important details of adjustment, is related to the alignment of the specimen and the water jet that will make its cooling. Therefore, the construction and proper alignment of a specimen has total relevance, so they will be made according to NBR6339 standard brazilian, to determine the measures to be followed.

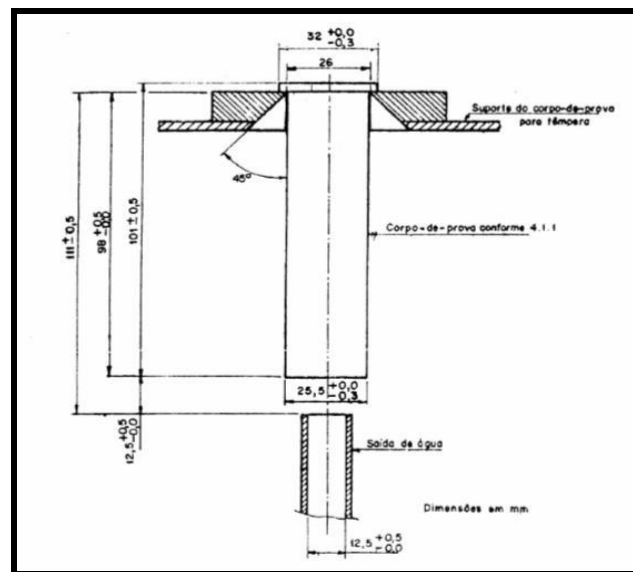


Fig. 6: Dimensions Test Bodies Second NBR6339 Standard. Source: [10]

The largest axis is $\varnothing 25.5 (+0.5)/(-0.0)$ x 98mm, and the "head" $\varnothing 32 (+0.0)/(-0.3)$ x 3mm.

III. RESULTS

After the construction and execution of a Jominy test on these materials, the respective curves illustrated in figures 7 and 8 should be obtained. It is important to note that a certain dispersion of test results under the same material is common, due to differences in steel structure in grain size inclusions and chemical compositions.

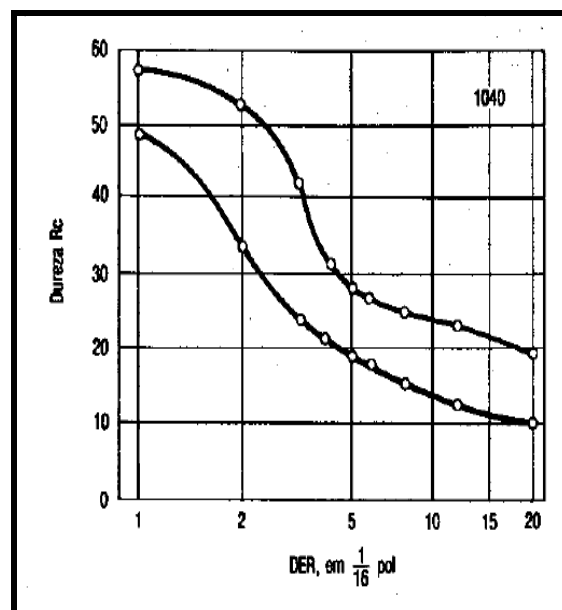


Fig. 7: Representation of Rockwell Hardness Test Points (HRC), Jominy Test of Steel Alloy SAE 1040. Source: [4]

Note that the red line corresponds to steel alloy 4140, while the black line corresponds to a derivative of it.

25, 2020. <https://www.materiais.gelsonluz.com/2017/10/aco-sae-1040-propriedades-mecanicas.html>;

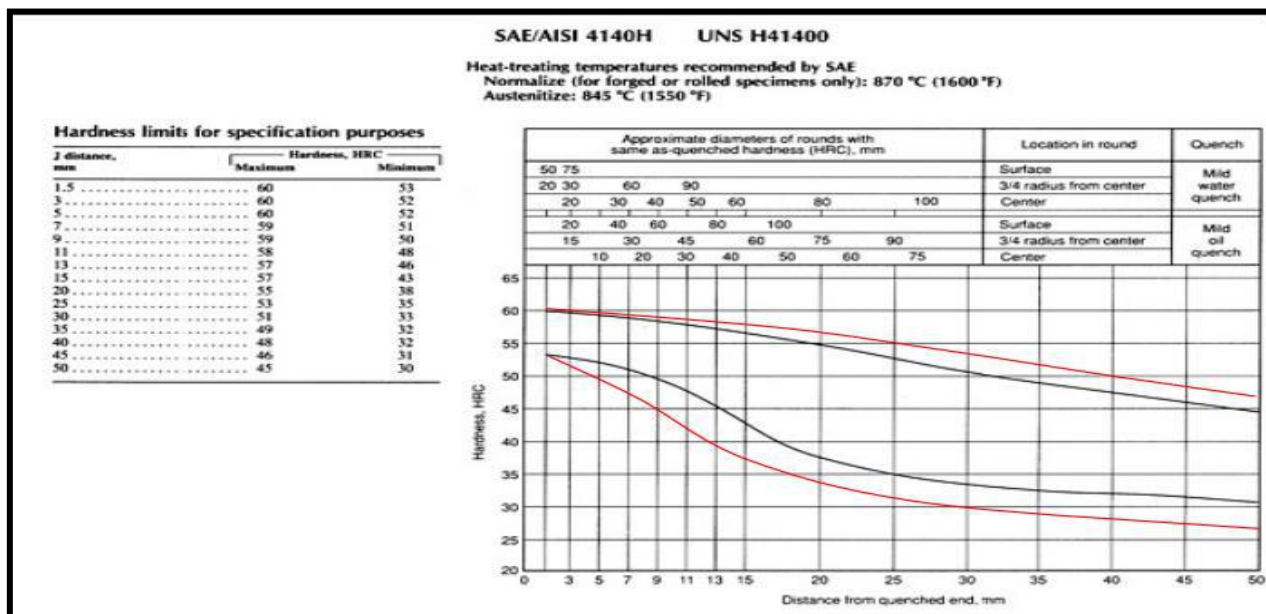


Fig. 8: Representation of Rockwell Hardness Test Points (HRC), Jominy Test of Steel Alloy SAE 4140. Source: [8]

IV. CONCLUSION

At the end of this project, it was possible to obtain knowledge of several types of steels alloy, because a whole research on steels alloy with suitable properties for Jominy trials was carried out. Besides acquiring several concepts and knowledge in various areas of mechanics, such as quenching processes, steel structures and their respective TTT and CTT curves, steel alloy constituents, for example austenite, martensite, ferrite and etc. Defining properties, as well as establishing the main requirements for assembly of a Jominy testing device.

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