THE ANNALS OF "DUNAREA DE JOS" UNIVERSITY OF GALATI
FASCICLE IX. METALLURGY AND MATERIALS SCIENCE
Nº. 3 - 2020, ISSN 2668-4748; e-ISSN 2668-4756
Article DOI: https://doi.org/10.35219/mms.2020.3.05

BED FRAME FABRICATION FOR HEAVY DUTY MACHINE TOOLS OR UNIQUE OF HIGH STRENGHT MATERIALS QUEND 700

Claudiu Ioan RUSAN, Cornel CIUPAN
Technical University of Cluj-Napoca, Faculty of Machine Building, Cluj-Napoca, Romania
e-mail: rusan.claudiu@comelf.ro, cornel.ciupan@muri.utcluj.ro

ABSTRACT

The purpose of the present work is to present new manufacturing technologies process of bed frame elements, especially those with a circular or conical section, made of high strength materials, new on the market. The research based on three methods to make this bed frame elements: cold deformation method, hot deformation method and cold deformation method after soft annealing. Experimental research is focused on how the steel behaves at high temperatures, in identifying an adequate improvement treatment for parts after soft annealing, to increase the mechanical properties of this and preparation of the welding procedure specification.

KEYWORDS: high strength steel, cold and hot deformation, metal rolling, welding

1. Introduction

This theme falls into the field of engineering sciences and materials sciences, aiming to identify new technologies and solutions for the construction of specific machine tool parts, such as base of structures, bed frames, columns, etc and unique large size parts.

The purpose pursued by this work is to provide solutions to reducing the masses, reducing material consumption, lowering costs and manufacturing time by using high strength steel products on the market.

Each machine tool has a certain constructive form, dictated by the size and configuration of the workpieces, the size of the stresses produced by the cutting forces and several requirements: functional, ergonomic, and aesthetic. The most important part, which mostly ensures the shape of the machine tool is the frame, because the parts or component subassemblies of the machine tools are mounted on the frame, with their freedom to perform relative or fixed movements.

The materials used in the construction of the frames must ensure good thermal conductivity, high corrosion resistance and adequate mechanical strength. The frames can be made in various variants, such as the following materials: gray cast iron, malleable cast iron, globular cast iron, alloy cast iron and steel, but they can also be made of welded construction of sheet metal, laminated profiles, etc. Steel, in the construction of frames, is recommended for those who work with high cutting forces, shocks and vibrations [1].

The resistance conditions influence the constructive form of the bed frames by the idea that it must ensure:

- high rigidity to exclude elastic deformations that occur during machining process but also to ensure the part, a dimensional accuracy according to the requirements;
- adequate resistance to vibration to ensure higher quality surfaces [2].

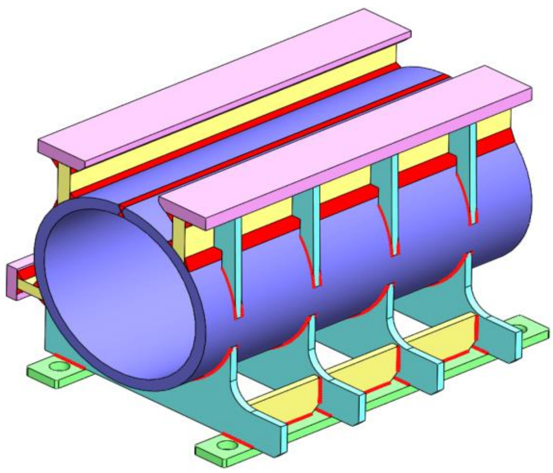

Fig. 1. *Rectangular profile bed frame with circular section*

THE ANNALS OF "DUNAREA DE JOS" UNIVERSITY OF GALATI
FASCICLE IX. METALLURGY AND MATERIALS SCIENCE
Nº. 3 - 2020, ISSN 2668-4748; e-ISSN 2668-4756
Article DOI: https://doi.org/10.35219/mms.2020.3.05

2. Bed frame elements made from fabricated steel-sheet products for welded construction

Regarding the realization of the bed frame elements by bending thick sheet metals, we can highlight several possible methods, for example: cold deformation, hot deformation, cold deformation after soft annealing.

The methods presented above have been applied experimentally, in turn to study and define an optimal technology for manufacturing the flat plates curved bed frame elements of high-strength materials such as Quend 700.

The following figure illustrates the cylindrical frame element made of sheet metal with a wall thickness of 50 mm and the quality of the material being Quend 700. Thus, during the development of the part, it is necessary to have an addition of material that will later be used making samples for mechanical tests and to study the behaviour of the material during the processes.

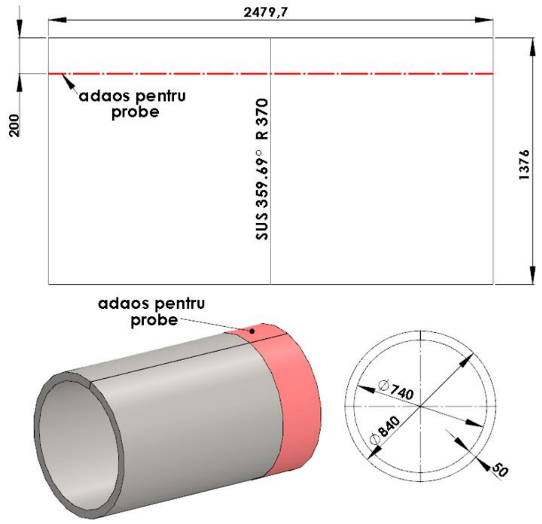

Fig. 2. *Execution drawing and development of the part*

Cylindrical and conical sheet metals rolling are obtained by bending between the rollers of rolling machines and welded along the generating line, so that the laminating fibre of the sheet obtained by rolling is in the annular direction (maximum load direction in the case of bed frames).

2.1. Cold deformation method

Cold deformation of sheet metal is done with the help of bending presses ("abkant") and rolling machines. Bending presses are used for pre-bending the ends of the sheet metal, this is mainly necessary when inserting it between the bending roller of the rolling machine.

The cold pre-bending of the Quend 700 sheet metal on bending presses requires a very high pressing force, because we need to overcome the mechanical properties of the material. If the pressing force does not overcome the mechanical properties of the material will result in the appearance of the springback phenomenon and the inability to achieve the pre-bending [3].

According to this method cold pre-bending of Quend 700 was tried on an Ermaksan Power-Bend, which develops a pressing force of 1000 tons over a length of 7100 mm. A punch with a radius of 50 mm and a lower die with an opening of 500 mm were used on the press machine, setting the properties of the material and the bending length of the part at 1376 mm, result the maximum force developed by the machine are around 300-350 tons/meter.

Fig. 3. *Press machine, Ermaksan Power-Bend 7100x1000 Ton*

Consequently, cold pre-bending of Quend 700 has failed due to the fact that this material has a very high yield strength of at least 700 MPa and tensile strength around 780-930 MPa, but mainly due to the inability of the equipment to develop a sufficiently high pressing force.

Fig. 4. *Lower die of bending press with opening of 500 mm*

N°. 3 - 2020, ISSN 2668-4748; e-ISSN 2668-4756
Article DOI: https://doi.org/10.35219/mms.2020.3.05

According to the input data, the thickness and bending length of the part, bending tools, we can estimate the effective pressing force Fmax required to achieve the pre-bending with the formula below [4].

$$F_{max} = \frac{1{,}6\ R_m\ t^2\ \alpha}{10\ V}\ [\frac{tons}{m}] \qquad (1)$$

Where, R_m is tensile strength in N/mm^2, t is sheet thickness in mm, α are angle coefficient in degrees (for 90° →1; 30° →1.6; 60° →1.6; 120° →1.6; 150° →0.7) and V is die opening in mm.

$$F_{max} = \frac{1{,}6\ x\ 871\ x\ 50^2\ x\ 0.7}{10\ x\ 500} = 487{,}8\ \left[\frac{tons}{m}\right] \qquad (2)$$

2.2. Hot deformation method

Hot deformation method consists in pre-bending and rolling the flat plate according to the following steps:

- heating the flat plate to 750 °C in the electric oven and performing the pre-bending operation on bending press;
- after the pre-bending on the flat plate follows the rolling on rolling machine 80x3500 up to a curvature value of R700;

Fig. 5. *Rolling machine 80x3500*

- reheating the semi-finished product to 750 °C and transported to another rolling machine, AKYAPAK Type AHS 25/35, capable of achieving the radius of curvature below R700 to close the cylindrical product with the addition of pre-bent material;
- the next operation is to cut the pre-bend addition (2x250 mm) and make the chamfers on the generators;
- then a final heating is done at 750 °C to complete the closing of the shell at a radius of R370 and spot welding on rolling machine, AKYAPAK Type AHS 25/35 before the release forces of rollers.

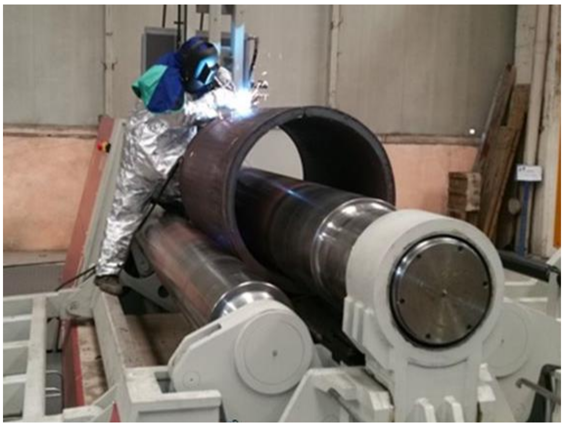

Fig. 6. *Closing of the shell at a radius of R370 and spot welding on rolling machine AKYAPAK Type AHS 25/35*

This method of manufacturing cylindrical frame elements from Quend 700 has been successfully developed but has some disadvantages that are not suitable for mass production, such as: the energy consumed by the electric oven is high for many heating and preheating, the mechanical properties of the material decrease and after the tests show, the tensile strength around 550 MPa and yield strength around 500 MPa.

Due to the results obtained from this method a third method shown below will arise.

2.3. Cold deformation method after soft annealing

Cold deformation method after soft annealing is characterized of cold pre-bending and rolling after a single heating at 750 °C and cooling in air of the flat plate product.

This method follows the phases of operations from the previous variant only this time the semi-finished product does not have to be heated during the pre-bending and rolling operations:

- performing the pre-bending operation on bending press
- after the pre-bending on the flat plate follows the rolling on rolling machine 80x3500 up to a curvature value of R700;
- transported to another rolling machine, AKYAPAK Type AHS 25/35, capable of achieving the radius of curvature below R700 to close the cylindrical product with the addition of pre-bent material;
- cutting the pre-bend addition (2x250 mm) and make the chamfers on the generators;

THE ANNALS OF "DUNAREA DE JOS" UNIVERSITY OF GALATI
FASCICLE IX. METALLURGY AND MATERIALS SCIENCE
N°. 3 - 2020, ISSN 2668-4748; e-ISSN 2668-4756
Article DOI: https://doi.org/10.35219/mms.2020.3.05

- after which a last a final closing operation of the shell at a radius of R370 and spot welding on rolling machine, AKYAPAK Type AHS 25/35 before the release forces of rollers.

According to the input data, the thickness and bending length of the part, bending tools, knowing the tensile strength after soft annealing, according to the Table 7, we can estimate the effective pressing force Fmax required to achieve the pre-bending with the formula below.

$$F_{max} = \frac{1{,}6 \ x \ 550 \ x \ 50^2 \ x \ 0.7}{10 \ x \ 500} = 308 \ [\frac{tons}{m}] \quad (3)$$

In conclusion, the heat treatment applied to this method aims at improving the plasticity properties of the material and is applied as a preliminary heat treatment before cold deformation, the temperature of the operation being approximately 750 °C, it being adopted depending on the chemical composition of the steel and the allotted time being between 1-2 hours, followed by a cooling in the air. At the same time, at the end of the fabrication of the cylindrical frame element, an improvement treatment must be applied according to Table 9, to raise its mechanical properties at least close to the initial state.

3. Technological stages

The technological stages follow step by step the process regarding the realization of the cylindrical and conical sheet metals rolling, from the dimensioning phase of the flat sheet metal until its complete closing, these stages are presented in more detail below.

3.1. Dimensioning the development

Calculation the length of the cylindrical sheet metal development [5]:

$$L = \pi * (D_i + s) \ [mm] \quad (4)$$

Where, D_i is inside diameter in mm, s is sheet thickness in mm, H are height of cylindrical part in mm.

To calculate the development of a conical part, it is necessary to determine several geometric parameters highlighted in the formulas below [5]:

$$D_m = D_i + \frac{s}{\cos\alpha} \ [mm] \quad (5)$$

$$d_m = d_i + \frac{s}{\cos\alpha} \ [mm] \quad (6)$$

$$G = \frac{H}{\cos\alpha} \ [mm] \quad (7)$$

$$tg \ \alpha = \frac{D_i - d_i}{2H} = \frac{D_m - d_m}{2H} \ [^0] \quad (8)$$

$$\beta = 2\pi \sin\alpha \ [rad] \quad (9)$$

$$Rp = \frac{\pi D_m - b}{\beta} \ [mm] \quad (10)$$

$$rp = \frac{\pi d_m - b}{\beta} \ [mm] \quad (11)$$

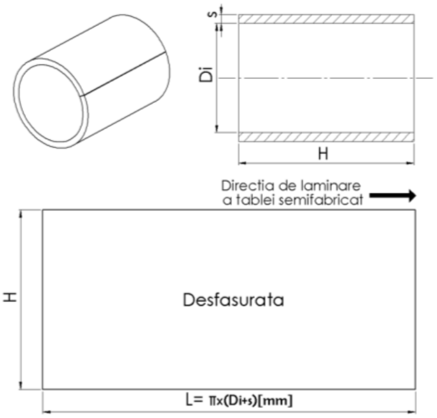

Fig. 7. *Cylindrical sheet metal development*

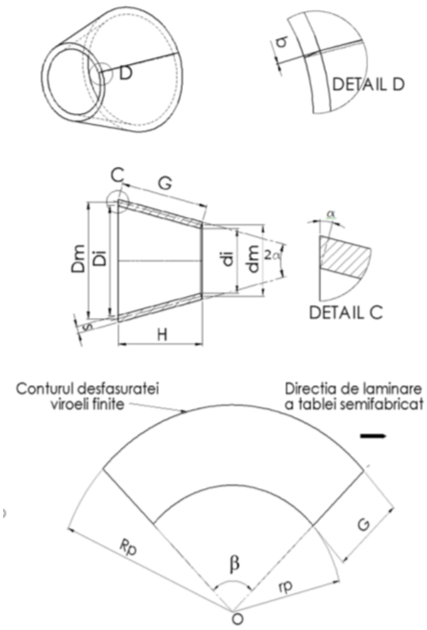

Fig. 8. *Geometric parameters of conical part and development*

N°. 3 - 2020, ISSN 2668-4748; e-ISSN 2668-4756
Article DOI: https://doi.org/10.35219/mms.2020.3.05

Where, is sheet thickness in mm, Di is maximum inside diameter in mm, di is minimum inside diameter in mm, Dm is maximum average diameter in mm, H are height of conical part in mm, G is side length of development in mm, b is the loft of conical sheet metal in mm, Rp is external radius of development in mm, rp is internal radius of development in mm.

3.2. The pre-bending process

According to figure 8 it is necessary to leave an addition at both ends to the length of the initial development since cutting, in order to be able to achieve the pre-bending on the press machine, this addition is necessary to have support on the lower die and the grip the pre-bend sheet metal on rolling machine.

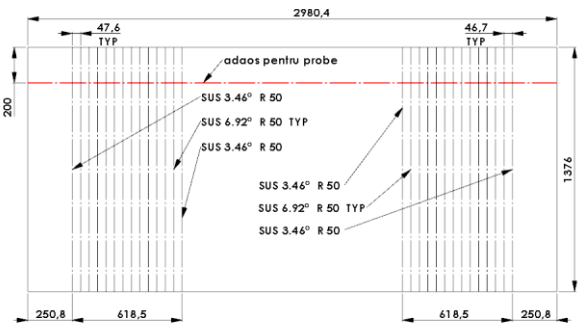

Fig. 9. *Development with pre-bending line*

The length of the development without the addition of pre-bending on the ends is 2479.7 mm, shown in Figure 2. With help of x-axis limiters of the press machine will be press on the line according to the dimensions on the development with pre-bending line drawing, and respecting the bending angles, see illustrated Figure 9. The bending starts from the length of 869.3 mm and will continue to the edge to a length 250.8 mm, with several bends equal to 14 and the size of step is equal to 47.6 mm.

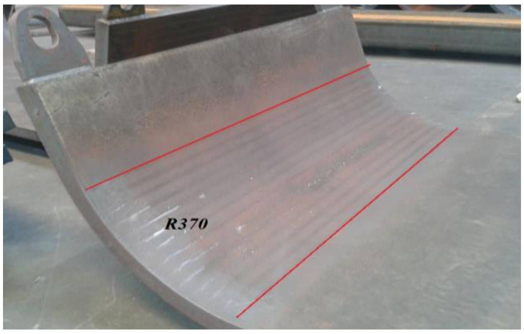

Fig. 10. *Pre-bending on press machine of the sheet metal ends at a radius R370*

At the end of the bending process, a radius check will be performed using a template with R370 mm on the entire width of the pre-bending sheet metal. The same will be done for bending the other end.

3.3. Rolling process of pre-bending plate

After pre-bending on press machine, it follows rolling on AKYAPAK Type AHS 25/35, capable of achieving the radius of curvature below R700 to close the cylindrical product with the addition of pre-bent material.

Fig. 11. *Curving the pre-bending plate on rolling machine*

3.4. Cutting excessive material process

After the pre-bending and rolling process, the addition left to the pre-bending process will be cut and then chamfers will be made for welding process. Cutting and chamfering will be performed in this case using manual plasma cutting device, followed by adjustment of the chamfer with an angle grinder acc. to the WPS (Welding Procedure Specification) documentation.

Fig. 12. *Manual plasma cutting of the pre-bend addition*

THE ANNALS OF “DUNAREA DE JOS” UNIVERSITY OF GALATI
FASCICLE IX. METALLURGY AND MATERIALS SCIENCE
N°. 3 - 2020, ISSN 2668-4748; e-ISSN 2668-4756
Article DOI: https://doi.org/10.35219/mms.2020.3.05

Fig. 13. *Chamfering at both ends of the cut addition*

3.5. Final rolling process

After cutting the pre-bend addition and making the chamfers in the longitudinal direction, next is final closing operation of the shell at a radius of R370 and spot welding on rolling machine, AKYAPAK Type AHS 25/35 before the release forces of rollers.

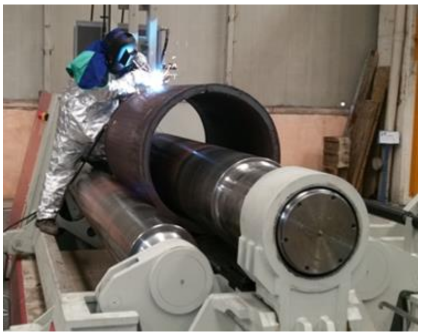

Fig. 14. *Final closing operation of the shell at a radius of R370 and spot welding on rolling machine*

3.6. Welding process and cutting addition

Welding process is a very important stage, it consists in the complete welding of the longitudinal loft according to the technology presented in chapter four, finishing it by grinding and removing of spit. The shell and the weld will be checked by the personnel responsible for performing the non-destructive and quality control.

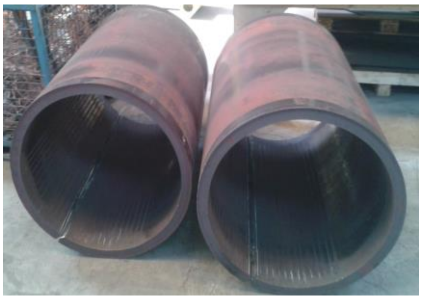

Fig. 15. *Preparation of metal shell for welding process*

Fig. 16. *Completion of the welding operation*

3.7. Calibration process

Calibration is the technological operation by which the deviations from the circularity of the sections are eliminated of cross sections in our case a cylindrical and conical sheet metals. Calibration applies only to rigid cylindrical and conical sheet metals, characterized by a ratio between the wall thickness (s) and the inside diameter (Di), which meets the criterion in the equation below.

$$\frac{s}{D_i} > 0.01 \qquad (12)$$

The calibration is also performed on the rolling machines and involves the following steps:

- checking the shape deviations of the cylindrical sheet metal to be calibrated and establishing the rc calibration radius (the radius at which the rolling machine is adjusted);
- preparing the cylindrical sheet metal, usually consisting in grinding the longitudinal increased height of weld;
- tightening the cylindrical sheet metal between the upper roller of the machine and the side rollers to ensure the calibration radius;
- checking the quality (shape accuracy) of the calibrated cylindrical sheet metal.

4. Custom welding procedure specification

Welding of Quend 700 can be performed using any of the conventional welding methods available both as manual and robotic welding. In the thickness range up to 30 mm, if a heat input of 1.7 kJ/mm is used, preheating prior to welding is not needed. Welding of Quend 700 is recommended to be performed at ambient temperature not lower than +5 °C. Subsequent to welding, let the welded parts slowly cool down to room temperature. Do never accelerate the cooling process of the weld. It is always recommended to use low hydrogen electrodes when welding Quend 700 [6].

THE ANNALS OF “DUNAREA DE JOS” UNIVERSITY OF GALATI
FASCICLE IX. METALLURGY AND MATERIALS SCIENCE
N°. 3 - 2020, ISSN 2668-4748; e-ISSN 2668-4756
Article DOI: https://doi.org/10.35219/mms.2020.3.05

Table 1. *Welding Procedure Specification (EN ISO 15609)*

Transfer mode	dip + spray + globular
Welding process	135(MAG; GMAW)
Joint type	BW
Weld preparation details (sketch)	
Method of preparation and cleaning	grinding
Parental material specification	S690 QL QUEND 700
Material thickness	t_1 =50 [mm] t_2 =50 [mm]
Welding position	PA (Flat Position)
Filler metal	EN ISO 16834-A: G 69 4 M Mn3Ni1CrMo / AWS A5.28: ER100S-G
Classification and trade name	FILCORD 100
Gas (Shielding)	EN ISO 14175: M21 – Arc – 18
Gas flow rate (Shielding)	15÷18 [l/min]
Gas Nozzle (diameter)	Ø16 [mm] inside diameter
Details of back gouging/backing	bs (both sided welding; root grinding and backing run)
Preheating temperature	T_p = +150 [°C]
Interpass temperature	+150 °C ≤ T ≤ +185 °C
Post-weld heat treatment	NA
Heating and cooling rates	NA
Weaving (maximum width of run)	string beads
Stand-off distance	15 ÷ 22 [mm]
Torch angle	Lead angle = 10°- 20°

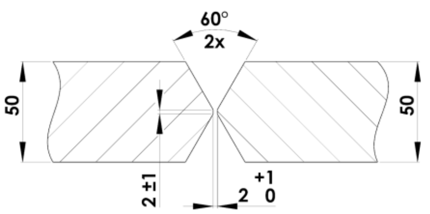

Fig. 17. *Joint design sketch*

Table 2. *Welding details*

Run	Tack+1	2÷8	9÷n
Process	135	135	135
Size of filler metal	Ø1.2 [mm]	Ø1.2 [mm]	Ø1.2 [mm]
Current	180÷190 [A]	260÷280 [A]	250÷270 [A]
Voltage	21÷23	27÷29	25÷27
Type of current/ polarity	DC^+	DC^+	DC^+
Wire feed speed	5÷6 [m/min]	9÷10 [m/min]	7÷8 [m/min]
Travel speed	13÷17 [cm/min]	26÷37 [cm/min]	22÷31 [cm/min]
Heat input Max.	10672 ÷ 16135 [J/cm]	9107 ÷ 14990 [J/cm]	9677 ÷ 15905 [J/cm]
Transfer mode	dip	spray	globular

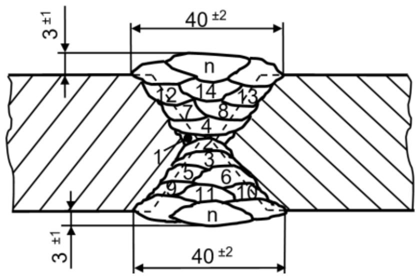

Fig. 18. *Welding sequences*

5. Properties of high strength material QUEND 700

Quend 700 is extra high yield strength structural steel obtained as a result of quenching and subsequent tempering with minimum yield strength 700 MPa [6].

5.1. Properties in initial state

Table 3. *Mechanical properties*

Yield strength $R_{p\ 0.2}$ [MPa]	**Tensile strength Rm [MPa]**	**Elongation A_5**
700 min	780-930	14% min

The following material product mix is currently available of thickness 4-64 mm and width 1500-3100 mm.

N°. 3 - 2020, ISSN 2668-4748; e-ISSN 2668-4756
Article DOI: https://doi.org/10.35219/mms.2020.3.05

Ultrasonic testing (UT) is used to identify such discontinuities as inclusions, cracks, and porosity. In thickness from 8 mm and higher, all plates are UT tested and controlled against class S2, E2 in accordance with EN 10160 [6].

Table 4. *Impact toughness*

Minimum values at		
0 °C	-20 °C	-40 °C
35 J	30 J	27 J

Table 5. *Carbon equivalent, typical value, %*

Plate thickness [mm]	CEV(1)	CET(2)
4 – 15	0.45	0.29
15.01 – 25	0.44	0.30
25.01 – 40	0.45	0.30
40.01 – 64	0.54	0.33

$$CEV = C+Mn/6+(Ni+Cu)/15+(Cr+Mo+V)/5 \quad (13)$$
$$CET = C+(Mn+Mo)/10+Ni/40+(Cr+Cu)/20 \quad (14)$$

5.2. Mechanical properties after soft annealing

This preliminary heat treatment is adopted for method three, the cold deformation method.

Following this heat treatment, the mechanical properties of the material will be reduced by up to 40% compared to its initial state, according to the results in Table 7. This helps to carry out the pre-bending and rolling operations of the semi-finished product with the equipment provided.

The main disadvantage is that a subsequent improvement treatment will be necessary to raise the mechanical properties, this treatment may involve water or oil quenching.

Table 7. *Mechanical properties after tempering*

Material: plate 50 [mm] Quality: QUEND 700			
Sample number	**1**	**2**	**3**
The heating temp. of sample [°C]	25 (initial state)	750	750
The force [N] obtained in the test d_0= 10 [mm]	70000	44500	44000
Rm [MPa]	891	566	506
Rp [MPa]	853	501	506
A_5 [%]	15	19	20
Z [%]	62.6	71.3	70.7
Impact toughness KV (-40 °C) [J]	162	44; 60; 82 → transversal 104; 106; 86 → longitudinal	

Table 6. *Chemical composition of Quend 700 in initial state* [6]

C	Si	Mn	P	S	Nb	Cr	V	Ti	Ni	Al	Mo	N	B
0.20	0.60	1.50	0.02	0.01	0.04	0.60	0.07	0.04	1.00	0.07	0.50	0.014	0.005

5.3. Mechanical properties when the Quend 700 are heated

In Table 8 are the results obtained from hot tensile test from Quend 700 in the initial state heated to different temperatures. As can be seen samples were heated to a certain temperature, but due to the time of handling and grip on the machine test they were cooled so in column three of the table the actual temperature at which the tensile test was performed was recorded.

With the help of a temperature gun measuring device, both the outlet temperature of the sample in the oven and the temperature before breaking the sample in the laboratory were measured.

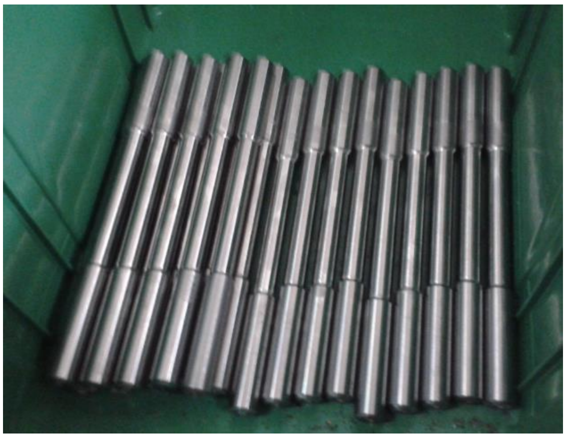

Fig. 19. *Samples test for hot tensile test*

N°. 3 - 2020, ISSN 2668-4748; e-ISSN 2668-4756
Article DOI: https://doi.org/10.35219/mms.2020.3.05

Fig. 20. *Stainless steel container*

The samples for tensile test were heated in the electric resistance furnace and transported to the physical-mechanical testing laboratory in a container made of a stainless-steel pipe lined with insulation (mineral wool) and sealed with a lid, see Figure 20.

The test report shows that the tensile strength decreases depending on the increase of temperatures according to the figures above, which led to the elaboration of the experiment from the second method of making bed frame elements. According to the results the lowest value of tensile strength is 220 MPa which was recorded at a sample temperature of 550 ºC. The yield strength could not be recorded due to the fact that the test was performed with heated samples.

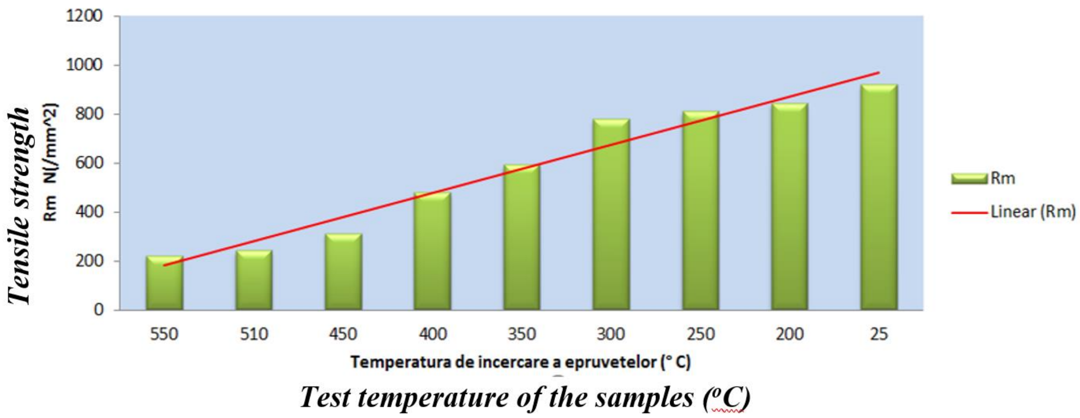

Fig. 21. *Behaviour of tensile strength depending on temperature*

Table 8. *Values of mechanical properties when the material is heated*

Material: plate 50 [mm], Quality: QUEND 700							
Sample number	**The heated temp. of sample [ºC]**	**Temperature of testing sample [ºC]**	**The force [N] obtained in the test d_0= 10 [mm]**	**Rm [MPa]**	**Rp [MPa]**	**A_5 [%]**	**Z [%]**
1	950	550	17500	220	-	40	94
2	950	510	19000	242	-	38	91
3	950	450	24500	312	-	44	87
4	780	400	37500	477	-	26.4	86.5
5	510	350	46500	592	-	15.3	84.8
6	460	300	61000	777	-	15.3	84
7	430	250	63500	808	-	15.3	68.6
8	350	200	66000	840	-	16.7	67.5

5.4. Tests to improve the material on samples

Tests to raise the mechanical properties are applied following the cold deformation and soft annealing method and its main purpose is to find an adequate heat treatment to raise the mechanical properties at least close to the initial state of the material.

The quality certificate of the Quend 700 material that accompanied its delivery indicates a tensile strength of 871 MPa and a yield strength of 830 MPa, respectively impact test KV at -40 ºC of 52 J, after soft annealing the mechanical properties of this material are as follows, the tensile strength of 566

N°. 3 - 2020, ISSN 2668-4748; e-ISSN 2668-4756
Article DOI: https://doi.org/10.35219/mms.2020.3.05

MPa and a yield strength of 501 MPa, respectively impact test KV at -40 °C of 86 J on the longitudinal fiber.

In order to make the test samples, two pieces of material were cut from the bed frame element made in method three and an improvement treatment was applied to the two pieces.

The first piece was heated to 900 °C and then water quenching followed by a tempering at 580 °C with staying time of an hour and a half respectively the second piece was heated to 900 °C and then oil quenching followed by a tempering at 580 °C with staying time of an hour and a half. The results of this tests can be found in the table below.

Table 9. *Mechanical properties after improvement treatments in water and oil*

Material: plate 50 [mm], Quality: QUEND 700							
Sample number	**The kind of improvement treatments**	**The force [N] obtained in the test d_0= 10 [mm]**	**Rm [MPa]**	**Rp [MPa]**	**A_5 [%]**	**Z [%]**	**Impact toughness KV (-40 °C) [J]**
1	25 (laminated state)	70000	891	853	15	62.6	162 170
2	The quenching in **water** at 900 ˚C and tempering at 580 ˚C with an hour's keeping with air cooling	63500 64750	808 824.8	745 789.8	14 14	69 68	36; 30; 18 → transversal 102; 120; 116 → longitudinal
3	The quenching in **oil** at 900 ˚C and tempering at 580 ˚C with an hour's keeping with air cooling	55000 51000	700 719	630 635	18 15	72.9 66	22; 18; 34 → transversal 94; 42; 102 → longitudinal

5.5. The improvement treatment applied to the bed frame elements

According to the results of the tests applied on the specimens from the previous subchapter in order to identify an adequate thermal improvement treatment for the cylindrical bed frame elements performed by method three.

The improvement treatment that gave the best results was water quenching and tempering, so it was decided to apply this treatment on the cylindrical bed frame elements.

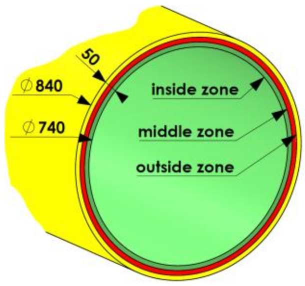

Fig. 22. *Highlighting the sampling areas after the improvement treatment*

Thus, the improvement treatment applied to the cylindrical bed frame elements consists in heating to 900 °C and water quenching in a special basin with bubbled water. After which a tempering to 580 °C will be applied for an hour and a half. From the additive material left on the final piece are made a series of samples for tensile and resilience tests and the results can be found in the table below.

The specimens were taken from the outside, inside and middle areas of the body of the frame element to see the effect of the improvement treatment in all areas of the material.

The most negatively affected area in a quenching and tempering is the middle one.

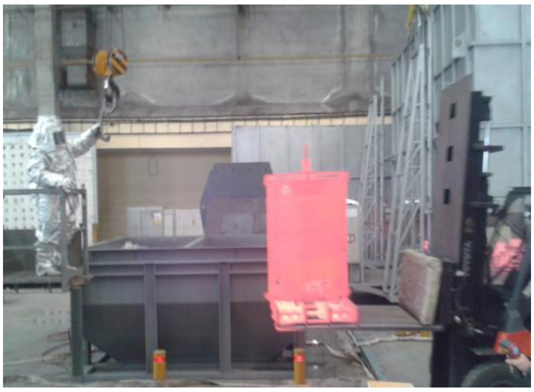

Fig. 23. *Introduction of the cylindrical bed frame elements in the basin with bubbling water*

Nº. 3 - 2020, ISSN 2668-4748; e-ISSN 2668-4756
Article DOI: https://doi.org/10.35219/mms.2020.3.05

Table 10. *The final improvement treatments in water applied to the cylindrical bed frame element*

Material: plate 50 [mm], Quality: QUEND 700				
Sample number	**1**	**2** Outside of the piece	**3** Inside of the piece	**4** Middle of the piece
Improvement treatment	25 ºC (initial state)	The **water** quenching at 900 ºC and tempering at 580 ºC with an hour and a half keeping		
The force [N] obtained in the test d_0= 10 [mm]	70000 70000	62000 64000	60000 59500	56000 56500
Rm [MPa]	891 891	789 815	706 700	713.4 719.7
Rp [MPa]	828 834	739 738	677 616	649 662.4
A_5 [%]	15 15	19 17	24 24	26 26
Z [%]	62.6 71.8	71.2 67.5	68 72	70.8 69.7
Impact toughness KV [J], **-40 [ºC]**	162 170	260 220	286 240	106 80

6. Conclusion

The manufacture of cylindrical or conical bed frame elements from Quend 700 can be achieved by several methods, most productive and economical method in our case being cold deformation after soft annealing. The cold deformation method can successfully replace the old methods of making bed frames or bed frame elements, among which we can mention the manufacturing process by casting, process that is high energy consuming.

Quend material exhibited superb mechanical properties including higher tensile strength, ductility and impact toughness and is therefore recommended in the manufacture of components for machine tools, who undergone high forces, shocks and deformations but can also be used in other applications such as: truck chassis, lifting equipment and many more.

According to the results of this study this material is not recommended be use for applications where the working and service temperature exceeds

References

[1]. Piotr B., Tadeusz N., Rafał G., *The welded CNC machine tool frame*, Czestochowa University of Technology, Institute of Mechanical Technologies, Czestochowa, Poland.
[2]. Botez E., Valda A., Velicu S., *Proiectarea maşinilor-unelte*, Editura dictatică şi pedagogică, Bucureşti, 1980.
[3]. Mori K., Akita K., Abe Y., *Springback behaviour in bending of ultra-high-strength steel sheets using CNC servo press*, International Journal of Machine Tools and Manufacture, vol. 47, p. 321-325, 2007.
[4]. ***, https://www.sm-tech.ro/files/Calculator-forta-aprox-indoire.xls, 2020.
[5]. ***, https://vdocuments.site/44241413-curs-tcmutd.html, 2020.
[6]. ***, http://www.jsoarescorreia.pt/wpcontent/uploads/1111/11/Quard-Quend-Datasheets_English.pdf, 2020.