MINISTRY OF EDUCATION
AND TRAINING

MINISTRY OF INDUSTRY
AND TRADE

NATIONAL RESEARCH INSTITUTE OF MECHANICAL ENGINEERING

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RESEARCH ON BACKWARD EXTRUSION TECHONOLOGY IN HIGH-STRENGTH LOW ALLOY - STEEL FOR MANUFACTURING PRESSURE PIPE

SPECIALIZED: MECHANICAL ENGINEERING

CODE No: 9520103

SUMMARY OF ENGINEERING Ph.D THESIS

HA NOI – 2019

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INTRODUCTION

1. Urgency of thesis

Mechanical technology plays an important role in mechanical industry. Products of mechanical working technology varies from box, container to pressure details such as pneumatic cylinders, pressure pipes, etc., which are used popularly with greater demand. However, most of these products are being imported from foreign countries, especially pressure pipe shaped supported for civil industry and defense. In order to step by step master technology and be proactive in production, serving localization program to replace imported products, it is necessary to study technology which is suitable to production conditions in Vietnam. Normally, pressure pipes are produced by clawing method from slab, however, in our conditions, production of slab is still difficult. In addition, steel sheet are also anisotropic, adversely affect on process of shaping and deforming after stroking. In order to take a initiative in raw materials as well as overcome anisotropy of steel plates used for drawing, backward extrusion process from (cast) cylinderic steel is considered as an effective solution to make pressure pipe shaped according to current domestic production conditions.

Backward extrusion is a shaping method in which metal flows from pressure chamber through outlet under force of pressure and flow of the metal is in contrast to applied force. Details after backward extrusion has been much improved mechanical properties and are suitable to manufacture of pressure tube-shaped details. This technology has been increasingly used widely and received much attention to develop technology, improving efficiency of backward extrusion to make pressure pipe shaped fittings. However, domestic research projects are not completed, professional or highly applicable in manufacture of pipe shaped details by backward extrusion technology. From aforementioned urgent problems, research thesis has been selected as follows: "***Research on backward extrusion technology in high-strength low-alloy steel for manufacturing pressure pipes*".**

2. Research objectives of thesis

Research on scientific and practical basis to apply backward extrusion technology of hot-dip alloy steel to manufacture pressure tube-shaped details, serving greater demand in domestic market.

3. Objects and research scope of thesis

- Research objects:

+ Deforming and shaping process of pressure tube-shaped details by backward extrusion method: stress distribution, deformation, organizational transformation, material stabilization.

+ Properties of high strength low alloy steel 30Х3МФ in process of backward extrusion serves for manufacture of body shell of anti-tank rocket.

- *Scope of research:*

+ Research on impact of deformation coefficient through ratio between inner diameter and outer diameter (d/D) and ratio between height and outer diameter (H/D) of products and shaping ability of pipe details during backward extrusion process.

+ Research on stress distribution, deformation, force graph in backward extrusion.

+ Initially research on organizational changes, mechanical properties after backward extrusion.

4. Research Method

Combine theoretical research with experiment research, in particular:

- Research on theoretical basis of metal plastic deformation and processes occurred in hot deformation and backward extrusion as a basis for simulation and experimental research.

- Apply simulation software to research and assess effect of ratio (d/D), (H/D) on ability of details shaping in backward extrusion. Determine effective working area, relationship function between (d/D), (H/D) to deformation degree and force as well as temperature as basis for experimental process.
- Build experimental system in accordance with objectives and research content. Use measuring, testing equipment and available software for data processing to ensure accuracy and reliability.
- Conduct empirical testing to confirm effectiveness and reliability of research method, evaluating experimental results as a basis for production of pressure pipes in Vietnam.

5. Scientific and practical significance of thesis

5.1. Scientific significance

- Research on application of theoretical basis of backward extrusion method in production of pressure tube-shaped details from high-strength low-alloy steel.
- Combine theoretical research with digital and experimental simulation in determining suitable working area of ratio (d/D), (H/D) on shaping process of details in backward extrusion.
- Investigate impact of ratio between inner diameter and outer diameter (d/D) and height with outer diameter (H/D) of pipe details to deformation degree (φ), force force (P). Thereby, we can create working area and relation function between (d/D), (H/D) and φ; P.
- Find distribution results of press and deformation in process of backward extrusion of alloy steel 30X3MΦ and define a suitable working area as a scientific basis for experimental process, ensuring deformation and shaping ability of details.
- Initially find organizational changes and improvemnet in mechanical properties of alloy steel 30X3MΦ after backward extrusion, meeting requirements of pressure pipe details.

5.2. Practical significance

- Research results of thesis contributes to development of mechanical working technology, being proactive in production of pressure pipe shaped details for civil and defense industries.
- Determine working area in accordance with ratio d/D = 0.77 ÷ 0.81 and H/D ≤ 3.6 to improve efficiency in backward extrusion.
- Determining appropriate temperature for backward extrusion of hot alloy steel (T = 1200^0C).
- Experimental results have successfully fabricated body shell of anti-tank rocket PG – 29 as basis of production of pressure pipes in Vietnam.
- Research results of thesis can be used as reference for teaching and research in field of mechanical working.

6. New contributions of thesis

- Build surveying method on impact of ratio (d/D) and (H/D) to deformation degree of force in backward extrusion of high-strength alloy steel. At the same time, define suitable working area of ratio (d/D) and (H/D) to maximum average pressure and the highest degree of equivalent strain.
- Determine size of bridge radius (R) of workpiece face, instead of workpiece with conical hole as real production, reducing error rate in backward extrusion.
- Determine rules of stress and deformation distribution in backward extrusion, thereby building the deformation model of material during alloy steel backward extrusion.
- Build an experimental system according to domestic research and production conditions; actively produce pressure pipes made from domestic produced cast steel.

7. Dissertation Outline

Beside preamble and tables of content, research content of thesis is presented in 04 chapters and general conclusion of thesis.

- Chapter 1: Overview on backward extrusion technology for pressure pipe manufacturing
- Chapter 2: Theoretical basis of material shaping deformation in backward extrusion
- Chapter 3: Research on hot-rolled steel backward extrusion by digital software
- Chapter 4: Experimental research on backward extrusion of alloy steel in hot state and application to manufacture of body shell of anti-tank rocket
- Conclusion and research methods in the future
- Reference, list of worked projects and appendix of the thesis.

CHAPTER 1: OVERVIEW ON BACKWARD EXTRUSION TECHNOLOGY FOR MANUFACTURING PRESSURE PIPE

1.1. Manufacturing technology of pressure steel pipe

Based on production technology and workpiece shape, we divided into two groups: Steel pipe fabricated by welding method and steel pipe fabricated by mechanical working method. Analysis of above methods shows that mechanical working is a suitable method for production of pressure pipe parts.

1.2. Some methods of pipe manufacturing by mechanical working

Pressure machining is a method of forming materials based on plastic deformation of metal. Because of chemical duration in shaping deformation process, mechanical properties are much improved compared to input material. Depending on input workpiece, product size, work requirements and equipment of production facility, we can choose appropriate method to produce different types of pressure pipes such as clawing methods; method of squeezing; rolling method; extrusion method.

From characteristics of above methods, in order to roactively choose input workpiece ss well as overcome anisotropy of steel plate used in drawing, ensuring that it is suitable for existing equipment, backward extrusion from cast steel workpieces made in Vietnam is an effective solution to fabricate domestic pressure pipe details. Backward extrusion under action of material press force according to ring opening formed between pestle and mortar, tube-shaped part is formed. In which metal is compressed in pressing chamber and organization changes and mechanical properties of material are greatly improved. Backward extrusion is shown in Figure 1.1.

Figure 1.1. Backward extrusion for manufacturing tube shaped details

1.3. Development of backward extrusion technology and application on pressure pipe manufacturing

- Backward extrusion of metal materials is used to produce pipe details from materials Al, Sn, Pb ... at normal temperature started from beginning of the nineteenth century and steel hot pressing only started from 1930s by designing mold systems, press rooms which can prevent high temperature and pressure.
- Backward extrusion technology is widely used in manufacture of pipe parts for civil industry (civil steel pipes, pressure vessels, etc.) and defense (military equipment, shells, body shell of anti-tank rocket, etc).

1.4. Research result on backward extrusion technology

** Research on backward extrusion technology on the world*

Backward extrusion technology which is used produce pressure tube-shaped details is getting more and more attention from scientists. Many research projects are implemented to develop, optimize technology amd improve product quality. Research mainly focus on following contents: Research method of backward extrusion; mold structure; squeezing force - system friction in backward extrusion; organizational structure and mechanical properties of material after backward extrusion; new methods in fabricating pipe details by backward technology.

** Research on backward extrusion in Vietnam*

There have been a number of domestic researches on steel backward extrusion technology in hot state and most of these works only finish at digital modelling and digital simulation. In fact, production of PG-29 body shell of anti-tank rocket by backward extrusion technology basing only on theoretical calculations and experience has not been met demand with high failure rate.

On basis of result analyzing of domestic and foreign research projects and required size for pipe details after backward extrusion, the thesis researchs impact of ratios between internal diameter and external diameter (d/D) and ratios between height and external diameter (H/D) of product on detail shaping process by research method: combining theoretical research, using digital and experiment simulation. The purpose is to find a suitable working area of these ratios and ensure that pipe detail requirement after backward has highest height and the thinnest wall thickness as well as high mechanical properties to meet requirements of pressure pipe details.

CONCLUSION ON CHAPTER 1

Overview on backward extrusion technology for manufacturing pressure pipe can withdraw some following conclusions:

- Due to deformation mechanical duration, mechanical working parts have good mechanical properties and high durability, so that mechanical working is considered as an appropriate solution in creating pressure pipe details for industry and defense.
- Backward extrusion can create pipe details with good mechanical properties thanks to principle of compressing metal blocks in pressing chamber to meet pressure requirements during working process. On the other hand, this method uses domestic cast steel castings, so it is completely active in input materials, regardless of supply as well as overcoming impact of anisotropy created in detailed shaping process by sheet steel. Therefore, backward extrusion is an effective solution for manufacturing pressure pipe details in our current production conditions.
- Currently, domestic research works only stop at research on modelling or digital simulation, there is no practical research for application of backward technology to produce resistant pipe details.
- On the basis of analyzing and evaluating requirements of product size in order to improve efficiency of backward extrusion, it is necessary to find appropriate working domain of ratio (d/D) and (H/D) so that pipe details after backward extrusion has the highest height and thickness, ensuring stability in detailed shaping process after the backward extrusion.
- Proposed appropriate research method: Combining theoretical research with using digital simulation to find appopriate shaping (of d/D; H/D) as a basis for experiment process is a reasonable and effective method.

CHAPTER 2: THEORETICAL BASIS OF MATERIAL SHAPING DEFORMATION IN BACKWARD EXTRUSION

2.1. Theoretical basis of plastic deformation

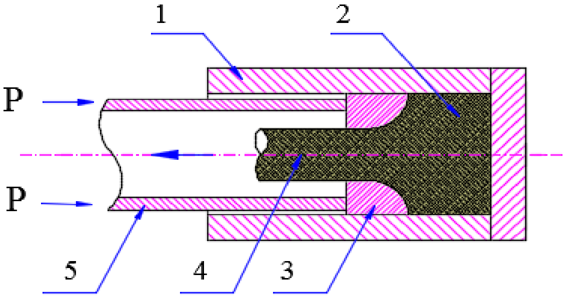
Theory research of metal plastic deformation is research on physical basis (shift of crystal structure, basic parameters of materials such as flow stress); and on mechanical basis (stress state, deformation and their relationship in process of metal plastic deformation). Thereby, it is basis for theoretical research of high strength low-alloy steel backward extrusion.

2.2. Theoretical basis of material duration after shaping deformation

Deformation duration is a phenomenon that stress increases according to degree of deformation in deformation process. In hot deformation, two following processes will appear: plastic deformation creates duration and hardeness, crystallize again and losing deviation. Backward extrusion of high-strength low-alloy is made in hot state. Therefore, research on mechanical duration in this process is research on that in hot state to achieve durable chemical requirements after backward extrusion.

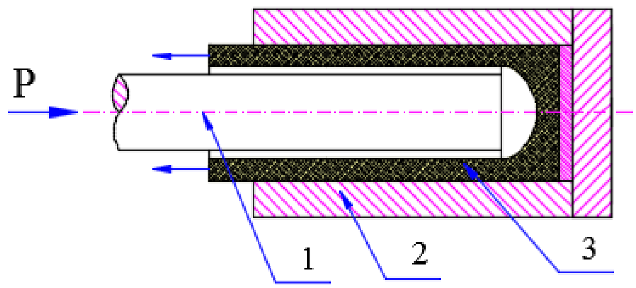
2.3. Theoretical basis of metal backward extrusion

2.3.1. Concept: Backward extrusion is a material shaping method in which metal flows from press chamber through vent under press and flow of metal against effective force.



1. Press chamber 4. product
2. Press metal 5. Empty preside
3. Press model

Figure 2.1. Backward extrusion diagram in plate details manufacturing



1. Compact press preside
2. Press model
3. Product

Figure 2.2. Backward extrusion diagram in pipe details manufacturing

Backward extrusion is used to manufacture plate shaped details or tube shaped details with limited length. Shape of exit hole determines cross section of product. Backward extrusion creates plate shaped detail as shown in Figure 2.1 and tube shaped details as shown in Figure 2.2.

2.3.2. Relationship between force and backward extrusion

Force and preside movement of in backward extrusion as shown in Figure 2.3.

In first stage, press increases.

Workpiece is deformed and filled up with mortar and the largest at the end of the stage. In second stage, force is unchanged because at this time, it is only affected by friction. In third phase, material mortar was almost deformed, creating a dead zone leading the force increase dramatically.

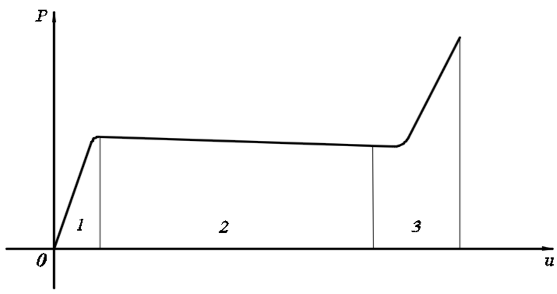


Figure 2.3. Relationship between force and extrusion backward extrusion

2.3.3. Specific pressure when preside is put into metal workpieces

Determining of specific pressure when pestle is put into metal workpiece (in the case that workpiece is semi-infinite space) can use liding path method (Figure 2.4 and Figure 2.5).

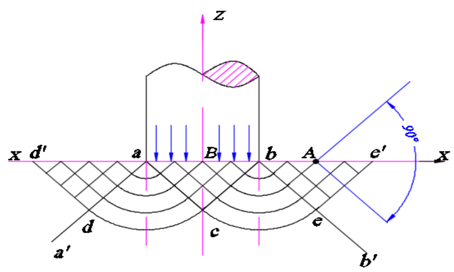


Figure 2.4. Sliding path when pestle starts into workpiece

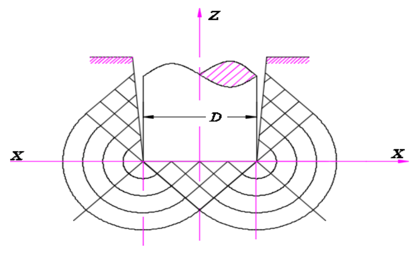


Figure 2.5. Sliding path when pestle was put into workpiece

Specific pressure $q = -\sigma_{ZB}$, so $\omega_{AB} = \pi/2$:

$$q = 2k(1 + \omega_{AB}) = 2k(1+\pi/2) \approx 2.6k_{f*} \quad (2\text{-}1)$$

In case that rotation angle $\omega_{AB} = \pi$ is equivalent to figure 2.5:

$q = 2k(1+3.14) = 4.14k_{f*}$ (2-2)

2.3.4. Distortion force in backward extrusion

When metal backward extrusion is flowed into open ring between pestle (1) and mortar (3) as shown in Figure 2.6.

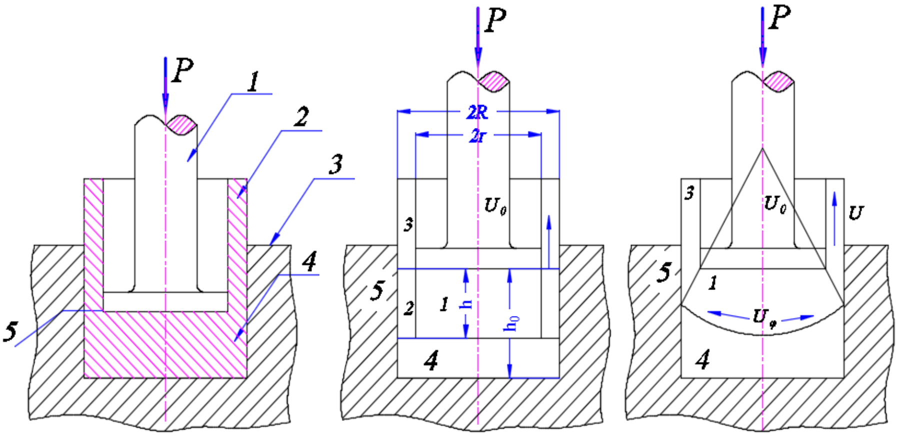


Figure 2.6. Diagram to define pressure in backward extrusion process

Total specific pressure is defined according to following formula:

Or:

$$q = \beta.k_f\left\{1{,}5 + \frac{1}{1-\frac{d^2}{D^2}}\ln\frac{D}{d} + \frac{h}{d}.\frac{1}{1-\frac{d}{D}} + \frac{h}{d}\left[\frac{1}{6} + \frac{\frac{1}{3}\frac{d^2}{D^2} - \frac{d}{D} + \frac{2}{3}}{2\frac{d}{D}\left(1-\frac{d^2}{D^2}\right)}\right]\right\} \quad (2\text{-}3)$$

Above equation shows that force or specific pressure is function of ratio d/D and h/D, but in survey process of height h of fixed area (1) and (2) area. This proves that d/D ratio affects force during backward extrusion.

2.3.5. Technology parameter in backward extrusion

Deformation level φ_p: $\varphi_p = \ln\frac{A0}{A1}$ (2-4)

In backward extrusion of thin-wall components, degree of deformation can also be calculated according to following formula:

$$\varphi_P = \ln\frac{D0}{D0-d} - 0.16 \quad (2\text{-}5)$$

Necessary deformation force in backward extrusion:

- In case that thickness of pipe wall is big: (S/D > 1/10) ↔ (S/D < 1/10) or d/D > 0,8

Deformation force: $F = \frac{A_0.k_{fm}.\varphi_P}{\eta_F}$ (2-6)

- In case that thickness of pipe wall is thin: (S/D ≤ 1/10) ↔ (1/2 >S/D ≥ 1/10) or d/D ≤ 0,8

Deformation force: $F = \frac{A_0.k_{fm}}{\eta_F}(2 + 0{,}25.\frac{h_0}{s})$ (2-7)

Deformation work: W = F. Sw. x (2-8)

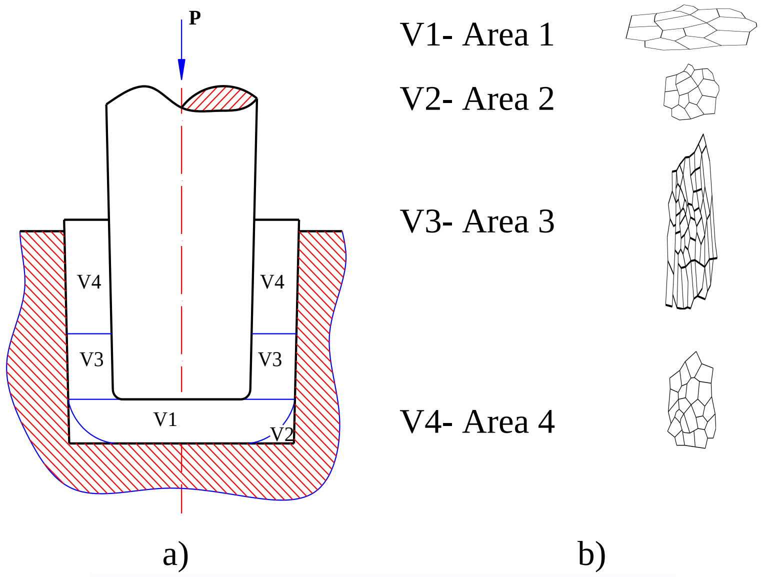
2.3.6. Change of metal crystal structure in hot state shaping

**** Change of metal crystal structure in forging - hot stamping of cast steel:***

When plastic deformation is organized, it results in breakdown of crystals and they will be stretched in direction of high flow intensity. With a high degree of deformation, nonmetals are stretched to receive fiber shape, creating a large grain organization. When distribution is suitable, it will create high durability. Growth of crystal particles continues even when forging-stamping process is finished. Therefore, forging finishing temperature should be made near allowed lower limit. When using crystallization chart again, it is possible to determine degree of deformation and temperature of deformation depends on size of desired crystal.

**** Change of metal crystal structure in hot-rolled steel backward extrusion***

Research on grain formation of metal in hot stamping process as well as recrystallization diagram of metal particles shows that metal after processing in hot state has a grainy structure and small metal particles go away. This increases mechanical properties of metals after machining. From there, give material model of details after pressing water as shown in Figure 2.7. With material model as shown in Figure 2.7, structure of metal is divided into regions of crystalline particles with different shapes and clear direction of movement. This material deformation model can be verified by numerical simulation and experimentation



a) Modell of object deformation at different area
b) Model of deformed grain at different area
Figure 2.7. Modell of object deformation after backward extrusion

2.3.7. Durability of low steel and high durability steel of detail after extrusion

In addition to change shape of particle size organization, grain direction when processing alloy steel in hot state also has a great change in organization, phases make the material durable after flowing backward. Oganization that achieved is martensite ram, transforms never to the end, so there exists a residual austenite organization. In addition, because in original alloy, there are durable chemical elements, so in organization is nearly equal to the above, there is also the participation of other phases and compounds. Aforementioned assumptions about material stabilization can be verified by analyzing material structure after backward extrusion.

2.4. Influence factors in backward extrusion

There are a number of influencing factors in backward extrusion: Temperature effects; effects of extrusion coefficients; effects of friction; effects of materials; effect of mold structure; effect of squeezing speed, etc in which temperature, extrusion coefficient, friction are main influencing factors in backward extrusion.

2.5. Choosing parameter in survey process:

- Temperature: Selection of pressing temperature is conducted based on study of material and actual production. However, selection of a specific temperature for backward extrusion can be done with help of a computer through numerical simulation software. From the simulation results, it is possible to select appropriate temperature to conduct a survey of backward extrusion as well as a basis for the experimental process.

- Coefficient of extrusion: Coefficient of extrusion is a characteristic quantity for reducing the area of section of a part after extrusion or it is the thinning coefficient of pipe element. In the case that the part with an outside diameter does not change, the degree of thinning is the change in the inner diameter of the part or the change in the ratio between the inner diameter and the outer diameter of the part (d/D).

- Friction: Friction in backward extrusion is caused by contact between the workpiece and the pressing device, specifically between the workpiece and pestle and mortar. The larger this contact area, the greater the friction and vice versa. In case the detail has a constant outside diameter instead of choosing the height H, consider the ratio between the height and the diameter of the product as the input parameter for the survey (H/D).

From analysis of influencing factors, size requirements, mechanical properties of pipe details after backward extrusion, the thesis continue researching to determine appropriate temperature for the backward extrusion, perform the simulation problem to investigate the influence of the ratio (d/D) and (H/D) to the degree of similar deformation. the largest force φ_{max}, maximum pressure P_{max} (is the value when the average pressure is stable at the highest level), find the appropriate domain of these ratios to ensure the requirement that the pipe detail after the backward extrusion has maximum height, thinnest wall thickness as a basis for experimenting to make pressure pipe details.

CONCLUSION ON CHAPTER 2

After researching on theoretical basis of process of material shaping deformation in backward extrusion, we draw some conclusions:

- Mechanism of metal plastic deformation is shift of lattice structure, displacement as well as increase density of deflection in the network, relationship between stress and deformation. Since then, it is the basis for studying process of stabilizing materials after deformation as well as building simulation and problems of backward test of high strength low alloy steel.
- The graph shows relationship between force and pressed stroke as a basis, criteria for evaluating results of research of backward extrusion technology by simulation software.
- Technological parameters in backward extrusion such as deformation, pressure and strain can be determined by mathematical formulas. In addition, under the help of computers by using numerical simulation software define the above parameters is a suitable solution to bring high efficiency in the survey process.
- Through research on structure, metal organization as well as material stabilization in process of deforming hot state plastic, thereby giving material models, crystal structures in different areas on details and make judgments about the durability of materials after backward extrusion. This model can be verified by simulation and experiment.
- Through the study of the influencing factors, the size of the pipe details after the backward extrusion has the highest height and the thinnest wall thickness. The thesis selects the ratios (d/D) and (H/D) as parameters to investigate the effect of temperature on the detailed shaping process and survey the effect of this ratio on degree of deformation. maximum equivalent φ_{max}, maximum pressure P_{max} by numerical simulation software.
- The temperature of backward extrusion of alloy steel is determined from research basis of material and actual production (T = 1200^0C), in addition to selection of temperature for backward extrusion can done by numerical simulation software.

CHAPTER 3: RESEARCH ON BACKWARD EXTRUSION OF HOT ALLOY STEEL BY DIGITAL SOFTWARE

3.1. Modeling of plastic deformation process of hot steel

Built math model includes basic assumptions, basic equations of continuous environmental mechanics and math models of backward extrusion due to plastic deformation.

3.2. Setting up a digital simulation math of backward extrusion of hot alloy steel

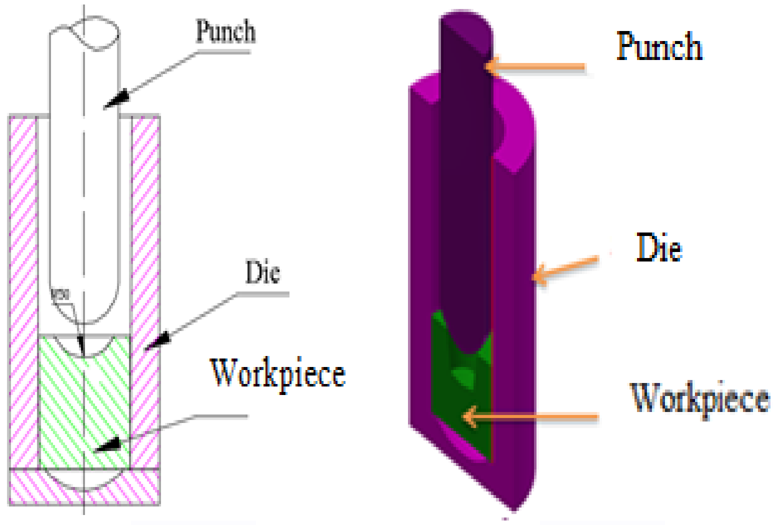
3.2.1. Application of digital simulation in mechanical working

Digital simulation has been widely applied in production research and deployment. It is considered as a development tool of mechanical working technology. Feature analysis of digital simulation software shows that Abaqus software is suitable for research on backward extrusion of high-strength low-alloy steel in hot state.

3.2.2. Setting sequence of digital simulation maths

To build a digital simulation maths, it is necessary to build inputting parameters, models and boundary conditions.

**** Geometric model:*** Building geometric models comes from exact requirements on geometric shapes and product sizes. Geometrical models include 3 objects of pestle, mortar and workpiece as shown in Figure 3.1



a) Model 2D *b) Model 3D*

Figure 3.1. Geometric model of backward extrusion

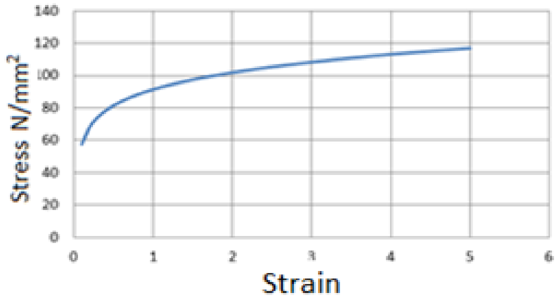


Figure 3.2. Stress and deformation curve of material 30CrMoNi5

**** Material model***: To simulate digitally hot backward extrusion, we must have stress - deformation curve of material, however, surveying properties of this material at temperature T = $\mathbf{1200^0}$C in our country faces many difficulties. Therefore, the thesis refers that properties of material 30CrMoNi5 which is equivalent to 30X3MΦ material at $\mathbf{1200^0}$C with deformation stress curve as shown in Figure 3.2 to put properties in digital simulation software.

**** Element grid model***: Select model 2D with element type CAX4R to perform simulation with different cases for investigation of alloy steel backward extrusion in hot state. Element grid of the workpiece is divided in deformation direction (flow) of material.

**** Boundary conditions:*** In simulation math of backward extrusion, the author selects face to face contact while workpiece is deformed and materials for pestle and mortar are considered as absolutely hard. Use graphite powder and oil to lubricate pestle and mortar during extrusion. The fiction coefficient between workpiece and extrusion device is $\mu = 0.5$.

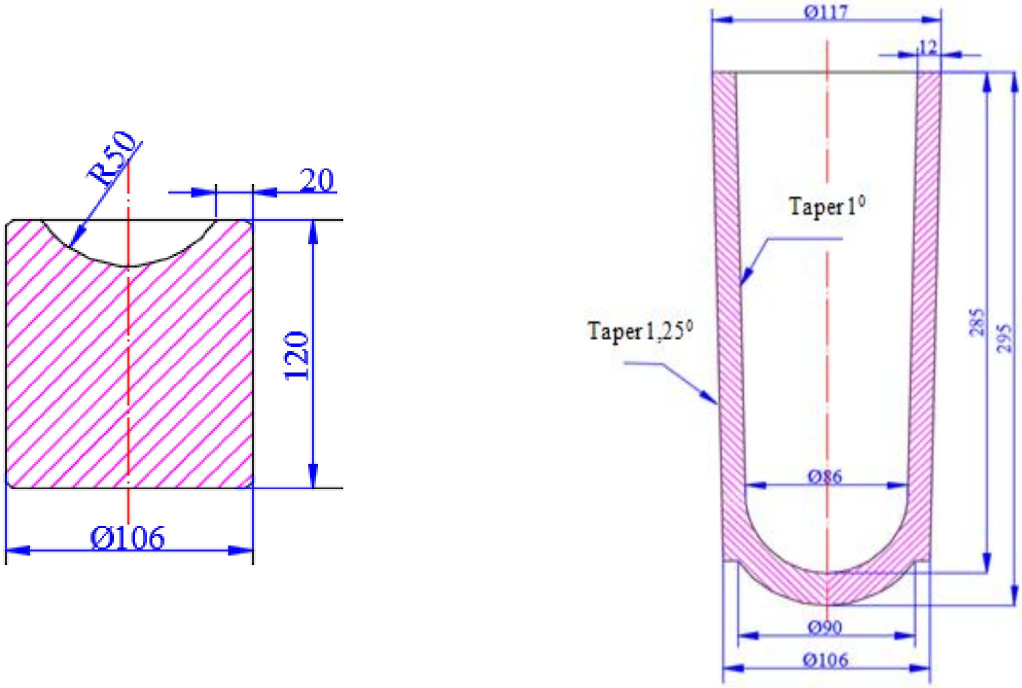
3.3. Simulate high-strength low alloy steel backward extrusion in hot state with digital simulation software

3.3.1. Chose survey area for parameters

From drawing of body shell of anti-tank rocket, calculating design of product size after extrusion is designed as shown in Figure 3.3 b in which d = 86 mm, D = 106 mm → d/D = 86/106 = 0.81; H = 295 mm, D =106 mm → H/D = 295/106 = 2,8. Select D = D_0, use Inventer design software to add residual (1%) for input workpiece size as shown in Figure 3.6a. In which, D_0 = 106mm, H_0 = 120, b = 20mm, to reduce error rate as in actual production, instead of designing the workpiece with a conical hole, we design workpiece with a sphere of radius R = 50 mm.

Select values of ratio d/D = 0.77; 0.81; 0.85; 0.89; 0.93 and H/D = 2.4; 2.6; 2.8; 3.0; 3.2; 3.4; 3.6; 3.8; 4.0; 4.2; 4.4; 4.6; 4.8. However, we divided into 2 ranges to survey. Range I have H/D = (2.4 ÷ 3.6) and range II has H/D = (3.8 ÷ 4.8). After conducting simulation of range I, we analyze and evaluate results received. If it is necessary, simulation will be conducted in about range II.

For purpose of re-examining determination of blast furnace temperature during low alloy steel backward extrusion, temperature survey on Abaqus software was performed for 35 different cases



a) Work piece drawing *b) Detail drawing after backward extrusion*

Figure 3.3. Wordpiece and detail drawing after backward extrusion

3.3.2. Simulation of alloy steel backward extrusion in range I

3.3.2.1. Simulation result in range I:

In this range, at each level (d/D), I only get some typical cases as following analysis:

+ Case 1: [d/D = 0.77; H/D = 2.4]

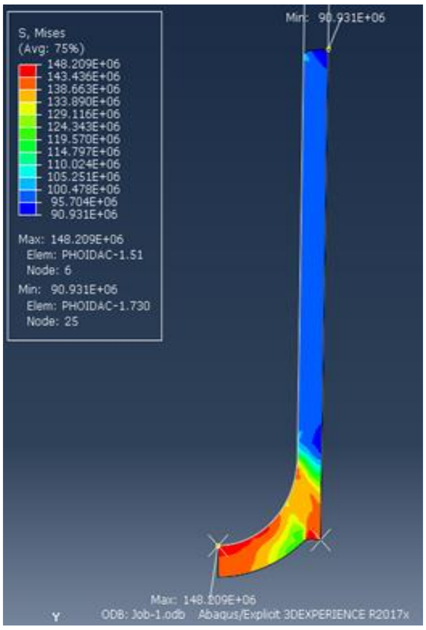


Figure 3.4. Press distribution is equivalent to Von Mises

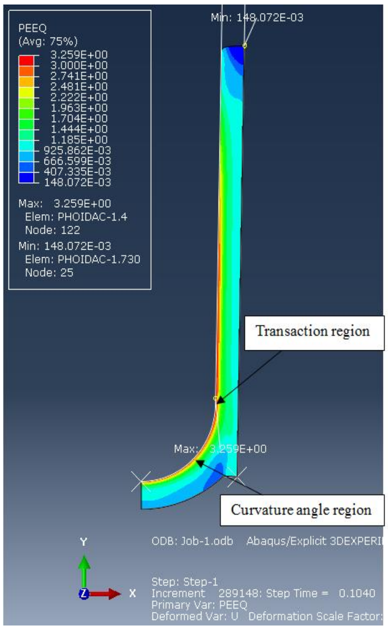


Figure 3.5. Deformation distribution is equivalent to Von Mises

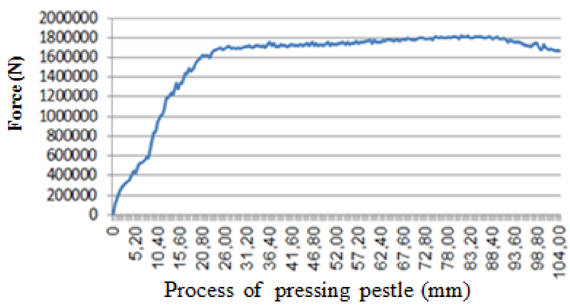


Figure 3.6. Force graph in process of pressing pestle

+ Case 2: [d/D = 0.81; H/D = 3.0]

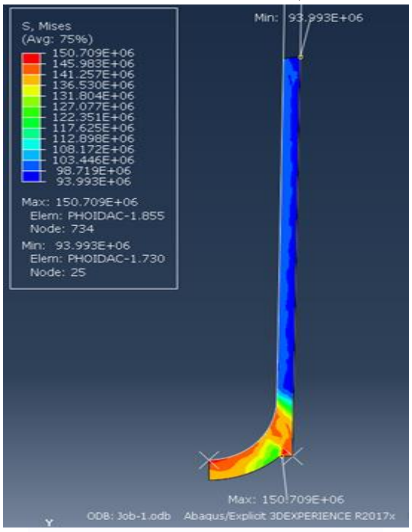


Figure 3.7. Press distribution

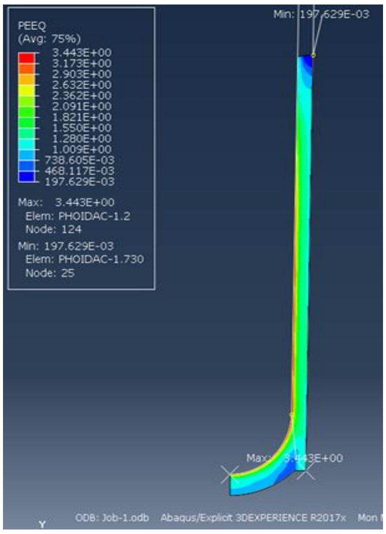


Figure 3.8. Deformation distribution

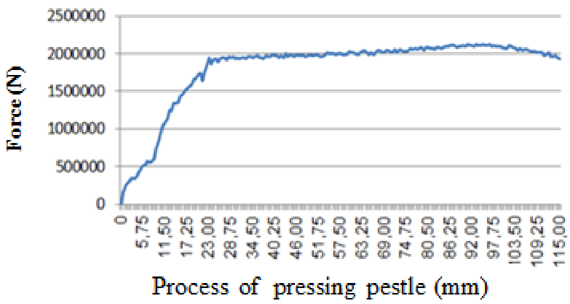


Figure 3.9. Force graph in process of pressing pestle

+ Case 3: [d/D = 0.85; H/D = 3.0]

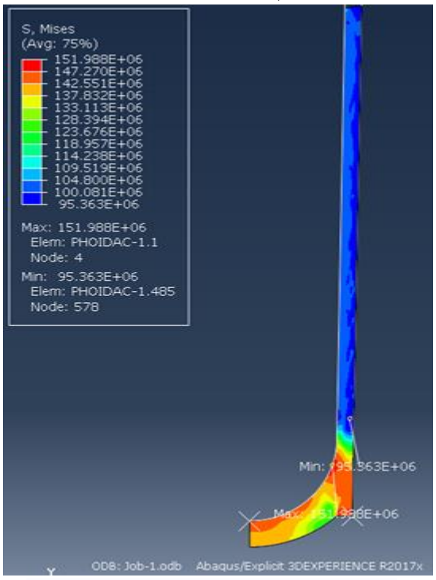


Figure 3.10. Press distribution

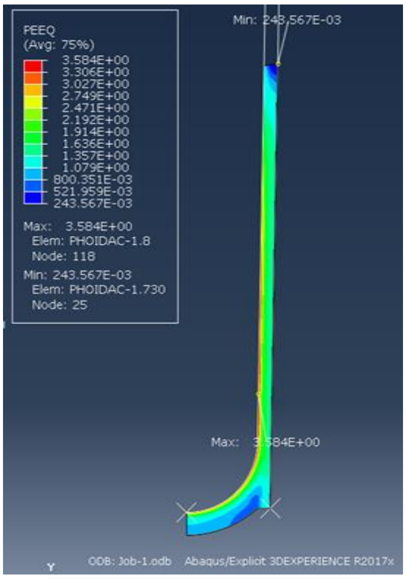


Figure 3.11. Deformation distribution

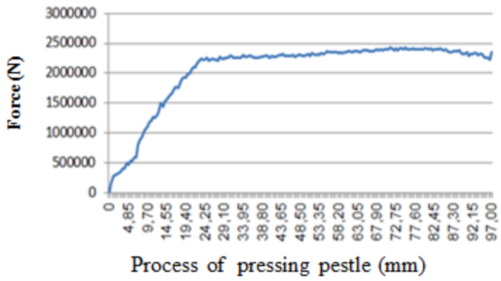


Figure 3.12. Force graph in process of pressing pestle

+ Case 4: [d/D = 0.89; H/D = 3.0]

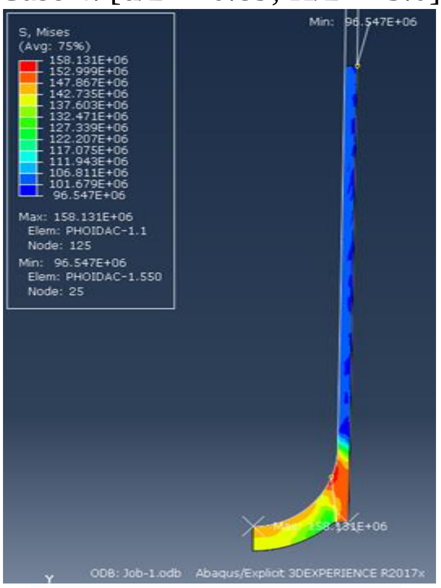


Figure 3.13. Press distribution

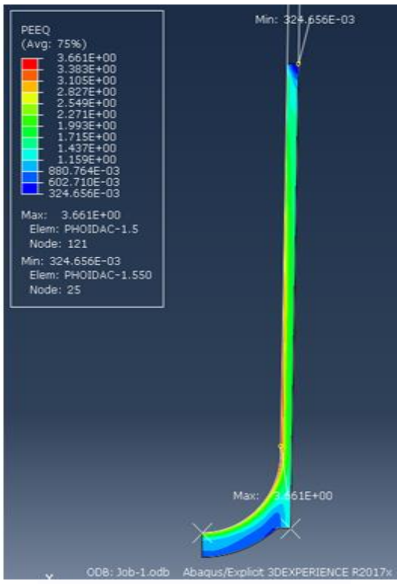


Figure 3.14. Deformation distribution

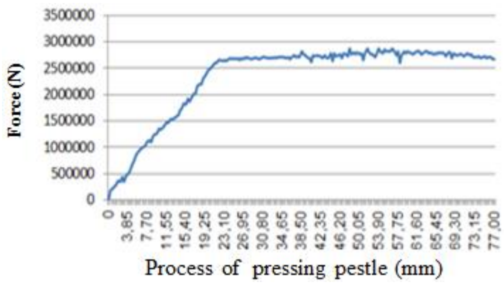


Figure 3.15. Force graph in process of pressing pestle

+ Case 5: [d/D = 0.93; H/D = 3.2]

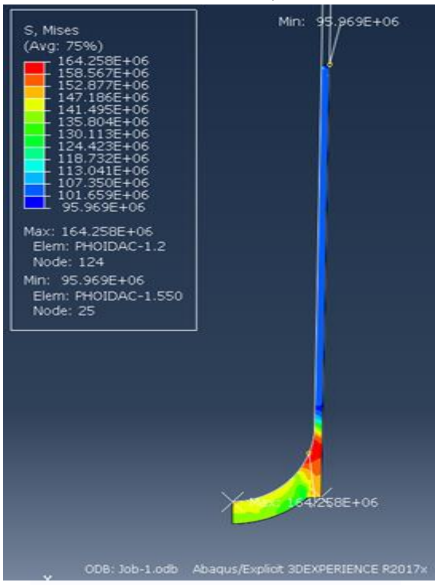


Figure 3.16. Press distribution

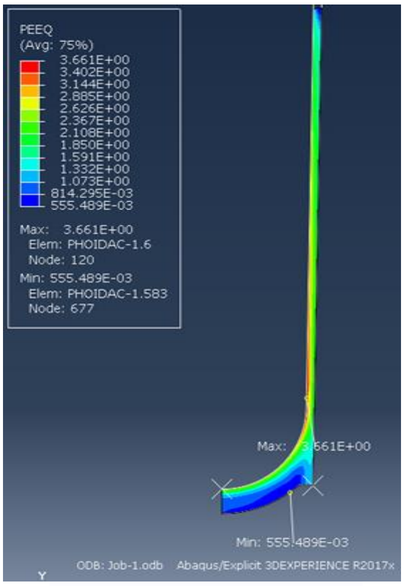


Figure 3.17. Deformation distribution

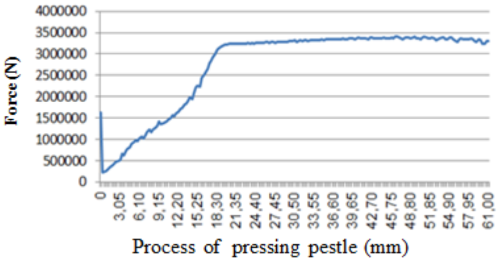


Figure 3.18. Force graph in process of pressing pestle

3.3.2.2. Analysis of digital simulation result in range I

a) Simulation result of survey on impact of temperature:

By analyzing digital simulation results of alloy steel backward extrusion for change of ratio (d/D) and (H/D), we define that when temperature changes, suitable temperature in backward extrusion is T = 1200^0C. This is consistent with research of materials and actual production. Therefore, it is possible to determine that backward extrusion temperature for steel 30X3MФ T = 1200^0C have relationship curve between stress and material deformation as shown in Figure 3.2.

b) Analysis of digital simulation result in range II

The simulation results are expressed through stress distribution, deformation, pressure force graph and also evaluation criteria for cases. Simulation results are suitable to satisfy above criteria simultaneously, these cases are basis for experimental process. When one or more indicators is not satisfied (not comply with rules), that case does not reach (type) and is not included in the experiment.

- ***When total thinness changes smallness***: d/D = 0.77 and d/D = 0.81, we have stress distribution on Figure 3.4 and Figure 3.7 which show that there is no stress concentration. The largest stress at detailed bottom area is directly subjected to load of pressed pestle, descending through transition area of part of the mouth because this area is only affected by friction force between workpiece and mortar and workpiece with pestles.

The highest deformation degree is shown in Figure 3.5 and Figure 3.8 in transitional zone, which is region with phenomenon of sliding, deflecting the most metal crystal network, gradually decreasing along length of wall and reaching the smallest price on the mouth. The pipe due to this position of the metal only moves from the bottom up to the phenomenon of less crystallization of the lattice, which is consistent with the deformation process in backward extrusion molding.

Figure 3.6 and Figure 3.9 showing pressure distribution: when pestle contacts with workpiece surface, the pressure force will increase deformed filled up the mortar. Press force reaches the highest value when flow of steel appears through gaps of pestle and mortar. When metal moves through the gap between pestle and mortar, press force was almost unchanged and force only create work to overcome friction.

Aforementioned analysis results show that when d/D = 0.77 and d/D = 0.81, there is stress distribution, deformation and pressure distribution diagram in accordance with backward extrusion.

- ***When thinness degree increases gradually:*** Consider case of d/D = 0.85 which showing stress distribution as shown in Figure 3.10. Stress has the largest redistribution of stress region, moving gradually from workpiece bottom to transition area and reaching the maximum in this region, however, stress distribution is implemented on a large area. Similarly, deformation degree has redistribution, the maximum value has moved through the transition area to component of detail as shown in Figure 3.11. Graph of force distribution tends to go up at the end of stage as shown in Figure 3.12, however, value is still stable. From redistribution of stress and strain, this case starts to appear abnormal signs that can cause instability in pressing process.
- ***When thinness degree continues to increase***: Considering case d/D = 0.89; d/D = 0.93: Aforementioned stress distribution is shown in Figure 3.13 and Figure 3.16: It is found that there is the largest stress concentration in a certain region, corresponding to case of d/D = 0.89; d/D = 0.93 above, Figure 3.13 and Figure 3.16 show that occurrence of "concentrated stress" region has the highest intensity and the middle of transition region. The area is very small, distributed throughout the material thickness (throughout detailed wall thickness), although distortion distribution has no unusual signs such as Figure 3.14 and Figure 3.17 but the graph of force distribution has any sign of no usually at 3.15 high amplitude of fluctuation in region 2 (stable area), especially in Figure 3.18 initially showing signs of going up, going down and then going up, this is not consistent with the rules of the map. Marketing of pressure distribution with this result, in practice, we should not carry out backward extrusion in areas with value of d/D = 0.89, 0.93.

By analyzing digital simulation results, appropriate domain of d/ D parameter to carry out backward extrusion is d/D = 0.77 ÷ 0.81 and rea that is capable of pressing is d/D = 0.85. At this time, limit of appropriate d/D technology domain search problem has been determined; we need to find the limited domain for H/D technology parameters. In order to achieve detailed purpose after backward extrusion of the highest height, ratio (H/D) must have the greatest possible value. Therefore, additional simulations of the cases (d/D) = 0.77 ÷ 0.85 should be conducted with values (H/D) of range II.

3.3.3. Simulation of backward extrusion of alloy steel in range II

Simulation is implemented when d/D = (0.77; 0.81; 0.85 and H/D = (3.8; 4.0; 4.2; 4.4; 4.6; 4.8), we have:

3.3.3.1. Simulation result in range II

a) Several press case with d/D = 0.77

+ Case (d/D = 0.77; H/D = 3.8)

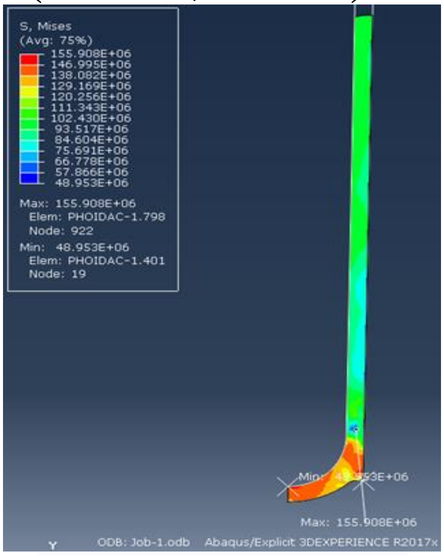


Figure 3.19. Press distribution

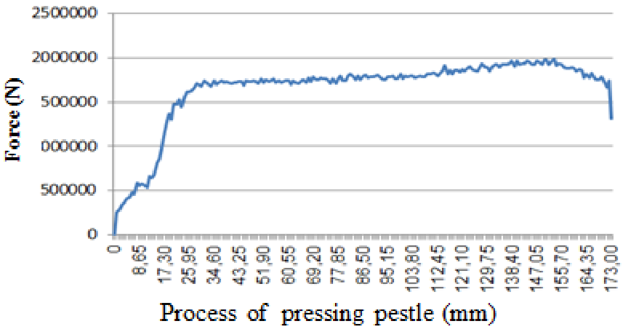


Figure 3.20. Force graph in process of pressing pestle

b) Some press path case with d/D = 0.81

+ Case (d/D = 0.81; H/D = 4.2)

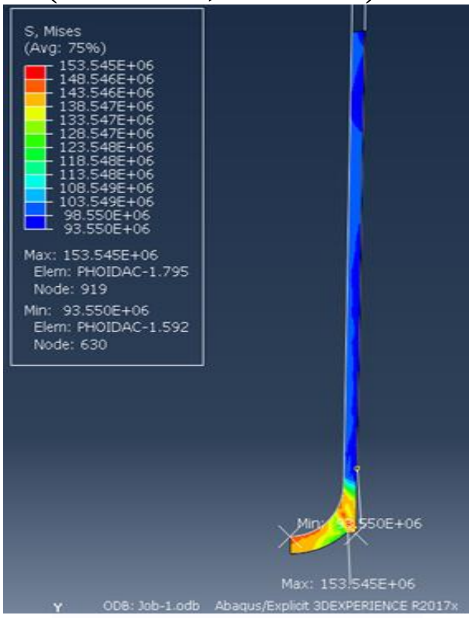


Figure 3.21. Press distribution

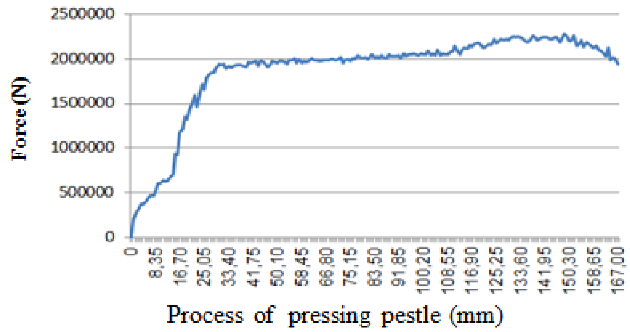


Figure 3.22. Force graph in process of pressing pestle

c) Some press path case with d/D = 0.85

+ Press case with (d/D = 0.85; H/D = 4.4)

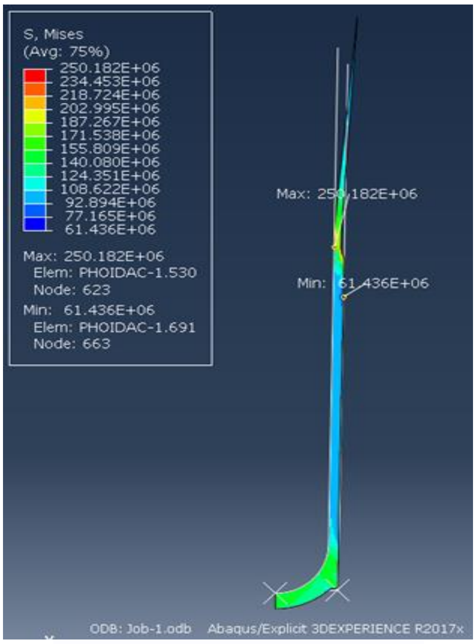


Figure 3.23. Press distribution

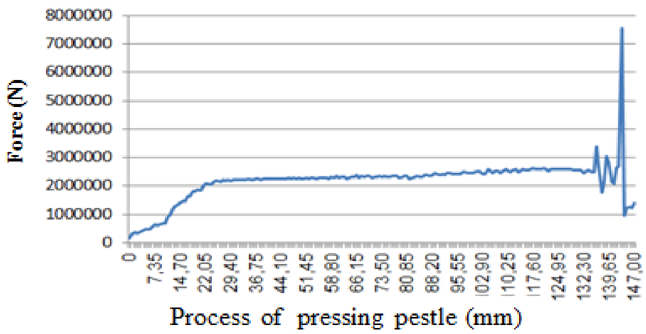


Figure 3.24. Force graph in process of pressing pestle

3.3.3.2. Analysis of simulation results in range II

- With case d/D = 0.77; 0.81: Consider the cases Figure 3.19 and Figure 3.21, these cases have an abnormal stress distribution. The region which has smallest stress value (min) always exists close to the region which has highest stress value (max), not follow distribution rule. In addition, on the pressure graph, there is also a force distribution that is not in accordance with general rule of backward extrusion. At the end of the journey, there is an abnormal downward movement shown on Figure 3.20 and Figure 3.22.

- With d/D = 0.85 as analyzing simulation results in range I, if d/D = 0.85, redistribution of the largest stress area happens and and no phenomenon of "stress concentration". However, case of H/D = 4.4 which is case of instability on details when simulating. This destruction can easily be observed on

Figure 3.23, at ligation position - destructive position has the highest stress concentration, abnormal force distribution pressure curve (sudden increase at the end of the period).) as shown in Figure 3.24.

From analysis of aforementioned simulation results, range II has stress distribution. Graph of distribution of pressure has anomalous distribution and the phenomenon of workpiece destruction in the process of extrusion. In the faction, it should not implement backward extrusion with values d/D = 0.77; 0.81; 0.85 when H/D> 3.60

3.4. Research on impact of ratio (H/D) and (d/D) on pressure and deformation degree in the backward extrusion process:

The digital simulation results give values of the equivalent deformation level and maximum pressure being summarized as in Table 3.1.

Table 3.1. The result of equivalent deformation level and maximum press by simulation

No.	d/D	H/D	Maximum equivalent deformation degree (φ_{max})	Maximum press force (Pmax)\ ton
1	0.77	2.40	3.259	179.4181
2	0.81		3.407	204.3661
3	0.85		3.532	228.6985
4	0.89		3.333	274.7555
5	0.93		3.007	332.7861
6	0.77	2.60	3.243	181.7809
7	0.81		3.411	205.8720
8	0.85		3.615	234.8450
9	0.89		3.478	275.9768
10	0.93		3.222	333.0645
11	0.77	2.80	3.261	185.4850
12	0.81		3.454	206.4891
13	0.85		3.634	239.2632
14	0.89		3.584	278.5485
15	0.93		3.409	334.3886
16	0.77	3.00	3.213	186.3175
17	0.81		3.443	209.0467
18	0.85		3.584	241.1944
19	0.89		3.661	280.0364
20	0.93		3.551	336.7397
21	0.77	3.20	3.255	186.7406
22	0.81		3.468	213.2653
23	0.85		3.568	243.6110
24	0.89		3.871	281.2083
25	0.93		3.661	338.7768

STT	d/D	H/D	Maximum equivalent deformation degree (φ_{max})	Maximum press force (Pmax)\ ton
26	0.77	3.4	3.235	190.3649
27	0.81		3.438	217.5091
28	0.81		3.623	245.5840
29	0.89		3.823	284.1270
30	0.93		3.801	339.2090
31	0.77	3.6	3.299	191.5107
32	0.81		3.446	218.9209
33	0.85		3.652	247.7649
34	0.89		3.834	288.1279
35	0.93		3.822	344.0247
36	0.77	3.8	3.291	191.775
37	0.81		3.470	220.998
38	0.85		3.571	248.758
39	0.77	4.0	3.415	196.972
40	0.81		3.433	222.850
41	0.85		3.620	252.206
42	0.77	4.2	3.312	199.318
43	0.81		3.408	223.162
44	0.85		3.615	253.612
45	0.77	4.4	3.305	202.645
46	0.81		3.427	229.298
47	0.85		3.702	258.742
48	0.77	4.6	3.291	204.586
49	0.81		3.405	231.487
50	0.85		3.656	260.699
51	0.77	4.8	3.703	209.023
52	0.81		3.462	234.227
53	0.85		3.652	262.268

3.4.1. Survey impacts of H/D, d/D on the maximum average pressure P_{max}

3.4.1.1. Survey impact of H/D on the maximum average pressure P_{max}

From simulation results on table 3.1 using Matlab software, we can draw a 2D chart showing the relationship between H/D and P_{max} in the cases d/ D = 0.77; 0.81; ... .0.93 as Figure 3.25.

From the chart, we can draw a comment:

- When H/D increases, press P_{max} increases in cases of d/D, the pressure is proportional to H/D. It means that press increases with height of the product accordingly, which is caused by friction factor between workpiece and mold wall, workpiece and pestles. At a small height (ie, small H/D), the friction force between workpiece and small deforming device leads to small pressure; press gradually increases when product height increases (i.e., H/D increases).

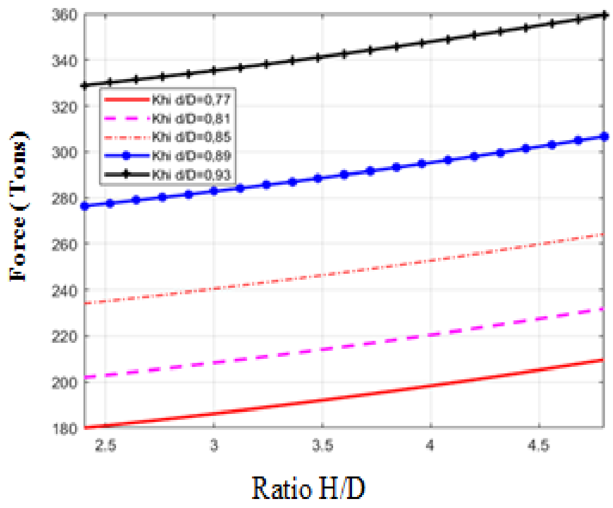


Figure 3.25. Graph of relation of press in H/ D ratio

- When thinness level increases (or d/D increases) from 0.77 ÷ 0.93 at each H/D value, the pressure increases. Because degree of thinness increases, the pest diameter increases leading contact area between pestle and workpiece increases, leading to increased pressure

3.4.1.2. Investigate impact of d/D on the maximum average pressure P_{max}

From simulation results on table 3.1 using Matlab software, we can draw a 2D chart showing the relationship between H/D and P_{max} in the cases H/D = 2.4; 2.6;...4.8 as Figure 3.26

From the chart we draw a comment:

- Relationship between P_{max} pressure and ratio (d/D) is proportional relation, with each H/D ratio showing the relative height of the product, the pressure increases when the degree of thinning becomes d/D increased from 0.77 ÷ 0.93. This is due to the increase in d/D, leading to an increase in the baseball d diameter, so the contact area between the pestle and the workpiece increases, leading to increased pressure.

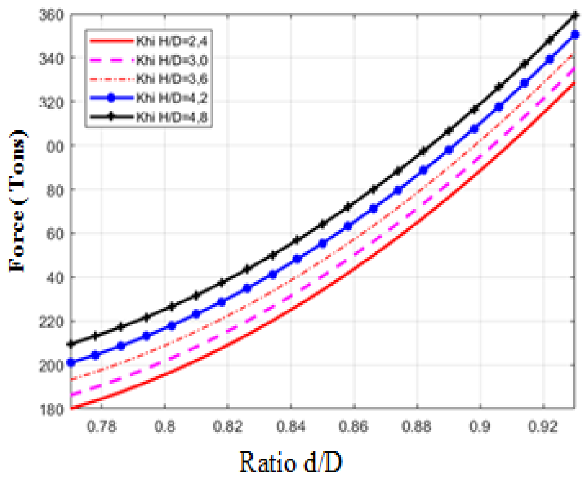


Figure 3.26. Graph of relation of press in d/ D ratio

- When the value of H/D ratios increases from 2.4 to 4.8 the pressure increases at each d/D value. This is because the friction factor between the workpiece and the pressing device increases, with a small H/ D ratio, the small H-height of the product, small friction force leads to small pressure, when H/D increases the force Increased friction leads to greater pressure.

3.4.1.3. Survey on simultaneously impact of ratio of H/D and d/D to the largest average pressure P_{max}

Considering press (P_{max}) is a function of H/ D and d/ D, choose the second polynomial of the variables.

$$P_{max} = a_1.(d/D)^2 + a_2.(H/D)^2 + a_3.(d/D).(H/D) + a_4\,.(d/D) + a_5.(H/D) + a_6$$

Using the least squares method after determining the coefficients we have the following regression equation:

$$P_{max} = 3173.(d/D)^2 + 1{,}097.(H/D)^2 + 2{,}915.(d/D)(H/D) - 4471.(d/D) + 2{,}15.(H/D) - 1725$$

Matlab software application has a graph showing the relationship between d/ D and H/ D with the largest average press P_{max} as Figure 3.27.

From the graph we draw the following remarks:

- For each d/D value, the force of P_{max} increases when H/D increases because of friction between the workpiece and the mold wall, workpiece and pestle.
- For each H/D value, the pressure of P_{max} increases when d/D increases this because the baseball diameter increases leading to the contact area between the pestle and the workpiece, increasing the pressure.
- When H/D and d/D increase, the maximum pressure of P_{max} increases, however, the increase of d/D will lead to the pressure increase faster than H/D. This proves that d/D affects more compressive forces than H/D.

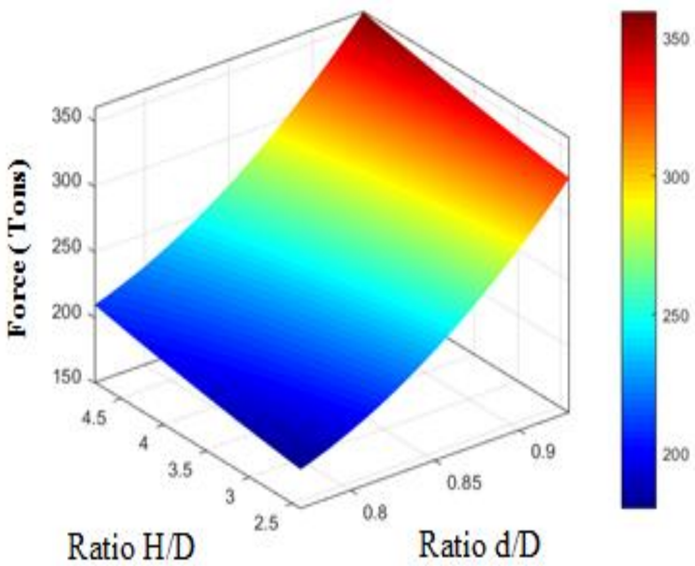


Figure 3.27. Diagram of relation of press in d/ D ratio

3.4.2. Survey impact of H/D, d/D on maximum equivalent deformation degree φ_{max}

3.4.2.1. Survey impact of H/D on maximum equivalent deformation degree φ_{max}

From the simulation results on table 3.1 using Matlab software, we can draw 2D diagram showing the relationship between H/D and φ_max in the cases d/D = 0.77; 0.81; 0.85; 0.89; 0.93 Figure 3.28.

From the graph, we draw a comment:

- When flowing with the ratio d/D = 0.89; 0.93 even if the H/D is small (H/D from 2.4 to 3.6), the graph slope is large, indicating that the degree of distortion increases very rapidly (suddenly) when increasing the product height. Increased, so the ability to destabilize the workpiece destroys when pressed. Therefore, in fact, it is not recommended to squeeze the pipe backward with the ratio of d/ D = 0,89; 0,93
- When the case d/D = 0.85 is applied even though the degree of deformation has stabilized (the slope of the graph has decreased), however, the value at the high distortion level φ_{max} can cause the current Workpiece destruction during extrusion (stability is not high).
- When extrusion of part thickness is not too thin (in case of d/D = 0.77; 0.81) and H/D ≤ 3.6 the degree of deformation is quite stable (slope of small graph) greatly affects the height of the product (H/D). When H/D> 3.6 compression levels increase rapidly (high) at H/D values when increasing from 3.8 to 4.8 this can destabilize and destroy the workpiece during extrusion. In fact, it is recommended to make backward extrusion of pipe details at d/D = 0.77; 0.81 and H/D ≤ 3.6.

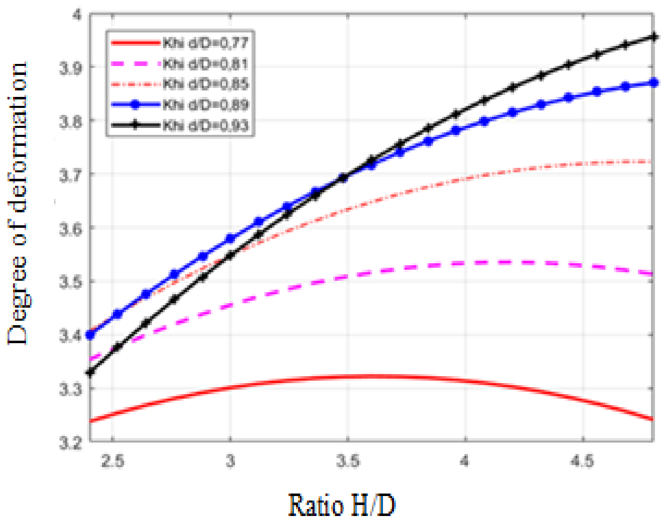


Figure 3.28. Graph of relation of deformation level in ratio H/D

3.4.2.2. Survey impact of d/D on maximum equivalent deformation level φ_{max}

From the simulation results on table 3.1 using Matlab software, we can draw a 2D chart showing the relationship between d/D and φ_{max} in the case of H/D = 2.4; 3.0; 3.6; 4.2; 4.8 Figure 3.29.

From the graph we draw a comment:

- When the height ratio is high H/D > 3.6 even when pressed in the case of extrusion with large details (small d/D from 0.77 ÷ 0.81) the degree of increased strain fast and sudden increase (slope of large graph) when d/D increases. A sudden increase in deformation may result in an abnormal phenomenon of the ability to destroy the workpiece during heavy extrusion. Therefore, it is actually not advisable to carry out tube flow injection with a height ratio of H/D > 3.6.

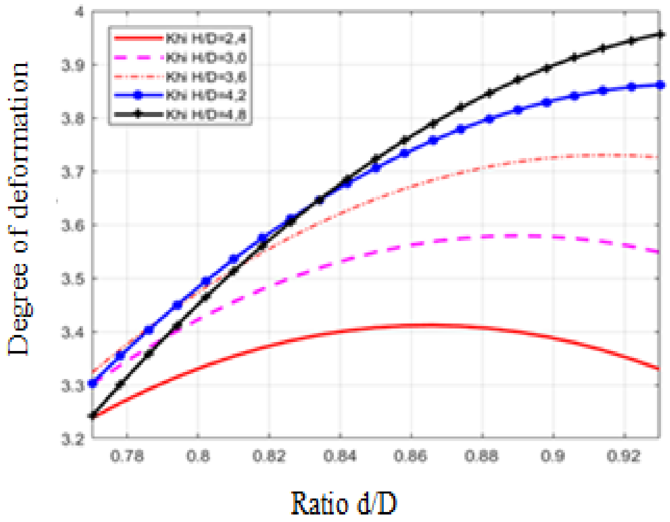


Figure 3.29. Graph of relation of deformation level in ratio d/D

- When the height ratio H/D increases from 2.4 to 3.6, the strain level increases rapidly (suddenly) in the values when the ratio of d/D increases from 0.89 to 0.93 so there is can cause instability to destroy workpieces during extrusion. Therefore, it should not be forced to flow in case of H/D and 3.6 and d/D = 0.89; 0.93.

- When H/D increases from 2.4 to 3.6 and d/D = 0.85, although the degree of deformation does not increase dramatically as above (d/D = 0.89; 0.93) but the value level High distortion can cause destruction when pressed.

- With the ratio of height H/D increases from 2.4 to 3.6 and the ratio of d/D increases from 0.77 to 0.81, the level of deformation is quite stable (small graph slope), value Its low. Therefore, it is completely possible to squeeze pipe details with height H/D ≤ 3.6 and the degree of thinning into d/D ≤ 0.81

3.4.2.3. Survey impact of H/D and d/D on maximum equivalent deformation level φ_{max}

Considering the maximum degree of equivalent deformation (φ_{max}) as a function of H/D and d/D, select the regression function of polynomial of the second degree of variables then

$$\varphi_{max} = a_1.\left(\frac{d}{D}\right)^2 + a_2.\left(\frac{H}{D}\right)^2 + a_3.\left(\frac{d}{D}\right).\left(\frac{H}{D}\right) + a_4.\left(\frac{d}{D}\right) + a_5.\left(\frac{H}{D}\right) + a_6$$

Using the least squares method after determining the coefficients we have the following regression equation:

$$\varphi_{max} = -19{,}33.\left(\frac{d}{D}\right)^2 - 0{,}05746.\left(\frac{H}{D}\right)^2 + 1{,}624.\left(\frac{d}{D}\right)\left(\frac{H}{D}\right) + 29{,}54.\left(\frac{d}{D}\right) - 0{,}8355.\left(\frac{H}{D}\right) - 8{,}71$$

Application of Matlab software has a graph showing the relationship between d/D and H/D with the highest degree of equivalent deformation φ_{max} as Figure 3.30.

From the graph we draw a comment:

- For each value of thinning level to d/D, the maximum deformation level φ_{max} increases when the ratio of H/D increases, which means that when H/D increases, it is more difficult to make backward extrusion.

- With value of H/D ratio increased at small values (H/D ≤ 3.6) at d/D values at small level (0.77 ≤ d/D ≤ 0.81) variable level stable increase form suitable for backward extrusion. In this range, when both d/D and H/D values increase, the deformation level increases. However, when d/D increases, deformation increases faster than H/D increases, it shows that d/D affects the degree of deformation more than H/D

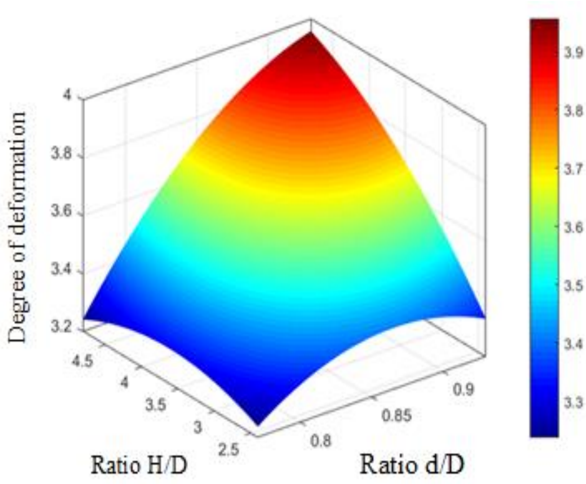


Figure 3.30. Diagram of relation of deformation level in ratio H/D and d/D

- With the value of H/D ratio increasing at a high level (H/D> 3.6) and hight deformation degree d/D ≥ 0.85, instable values lead to difficulty in backward extrusion and workpiece destruction in backward extrusion.

CONCLUSION ON CHAPTER 3

Researching on backward extrusion of hot alloy steel by digital software has drawn some following conclusions:

- Built digital simulation math, determining rules of stress distribution, deformation and press force by Abaqus software. Results are consistent with rules of backward extrusion studied from theoretical basis.

- From research result on impact of temperature on detail shaping process, determining appropriate temperature of low alloy steel backward extrusion is T = 1200^{O}C. This temperature is selected for digital simulation math to examine impact of ratios of d/D and H/D on the detailed shaping process as basis for experimental process.

- Determine suitable working area for d/D and H/D ratios, product height after backward extrusion depends on degree of thinness of that product and vice versa, specifically:

+ When pressing at ratio d/D = 0.77; 0.81 and H/D ≤ 3.6, these cases have stress distribution, deformation, pressure graphs in accordance with the law and there is no stress concentration phenomenon, value of deformation degree is stable.

+ When pressing at ratio d/D = 0.85, redistribution of stress region will start and degree of deformation at high level φ_{max} and 3,6 and pressure graph does not follow laws, causing workpiece destruction at 8% during survey.

+ When pressing at ration d/D = 0.89; 0.93 these cases produces phenomenon of "stress concentration", a sudden increase in deformation will cause workpiece destruction during extrusion. This indicates that thinning pressures into d/D = 0.89; 0.93 is unreasonable.

- For each case of variable thinning level (d/D) is constant, the pressure increases when increasing the product height (H/D). This is due to friction factor, when pressing details with a large friction height between the workpiece and a large pressing device leads to high pressure.

- When squeezing details, the degree of thinning (d/D) gradually decreases (i.e., d/D increases from 0.77 ÷ 0.93), the pressure increases, due to the thin wall thickness leading to the increase in the baseball diameter. The contact area between the pestle and the workpiece increases, so the pressure increases.
- Has built a mathematical function to represent the relationship between (d/D) and (H/D) to the degree of maximum equivalent deformation φ_{max} and maximum pressure P_{max}. As a basis for experimenting to make backward extrusion of hot alloy steel.

CHAPTER 4: EXPERIMENTAL RESEARCH ON BACKWARD EXTRUSION OF ALLOY STEEL IN HOT STATE AND APPLICATION TO MANUFACTURE OF BODY SHELL OF ANTI-TANK ROCKET

4.1. Experiment research on backward extrusion technology

4.1.1. Experimental material

**** Experimental material:*** Body shell of anti-tank rocket PG-29 is made of steel which is equivalent to 30X3MФ grade (according to ГОСТ 4543-71), requiring low P, S content and chemical composition in table 4.1 and mechanical characteristic in table 4.2 (good heat treatment I + high ram).

Table 4.1. Chemical component of material 30X3MФ

Target name, %						
C	Si	Mn	Cr	Mo	V	P;S
0,27 ÷ 0,34	0,17 ÷ 0,37	0,30 ÷ 0,60	2,30 ÷ 2,70	0,20 ÷ 0,30	0,06 ÷ 0,12	≤0,035

Table 4.2. Mechanical properties of material 30X3MФ

Liquid limit σ_c, MPa	Duration limit σb, MPa	elongation δ, %	Tightening φ, %	Impact degree, J/cm^2	Hardness HB
850	1000	12	55	100	229

* ***Experimental material (input workpiece):*** Material used in experiment of thesis is alloy steel made in Vietnam, which has been treated to improve quality (electric slag casting + forging) used for fabrication of anti-tank bullet casings through the following principles: backward extrusion, thinning, heat treatment, taper and mechanical processing. After casting, check chemical composition of materials with results as shown in Table 4.3.

Table 4.3. Mechanical component of steel 30X3MФ of the thesis

Target, % (volume)									
C	Si	Mn	Cr	Ni	Mo	Al	V	P	S
0,3301	0,2756	0,3731	2,4897	0,0895	0,2466	-	0,0972	0,0145	0,0044

After forging, workpiece are carried out mechanical and organizational test: Mechanical and organizational test specimens of workpiece are cut in two perpendicular directions. The first direction is axial direction of workpiece, the second direction is perpendicular to axis as shown in Figure 4.1. Figure 4.2 is location diagram of microorganism organization test pattern. Pull testing results like Table 4.4 to test hardness and toughness and dam like Table 4.5.

Figure 4.1. Image of input workpiece to cut mechanical sample of material

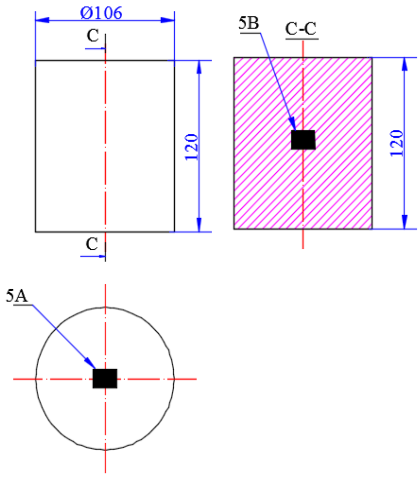


Figure 4.2. Diagram of sampling position to take photograph on input workpiece

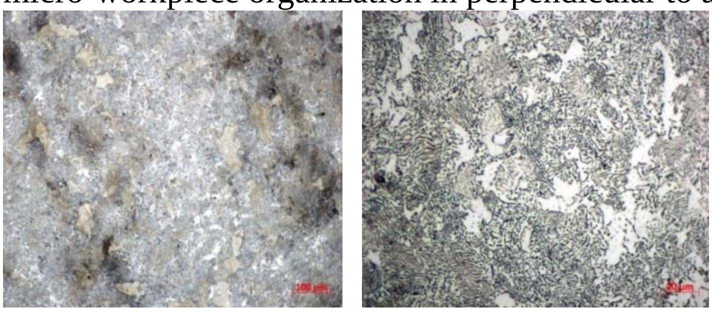
Table 4.4. Mechanical properties of thesis is in two directions perpendicular to input workpiece

Sample name	Dimension		*Testing results*					
	Diameter D_0	Intinital length L_0	Flow force F_e	Flow pressure R_e	Durability stress F_m	Duration press R_m	Elongation A	Tightening S
	mm	mm	kN	MPa	kN	MPa	%	%
Sample 5A-1 (perpendicular to the axis)	10,0	50,0	27,5	351	44,8	570	26,0	55,1
Sample 5A-2 (perpendicular to the axis)	10,0	50,0	26,6	338	45,5	579	22,0	53,8
Sample 5B-1 (axial sample)	9,9	50,0	26,0	338	43,3	563	22,0	52,8
Sample 5B-2 (axial sample)	10,0	50,0	26,2	333	44,2	563	24,0	53,8

Table 4.5. Mechanical properties of input material (stiffness, impact resistance) thesis is in two directions perpendicular

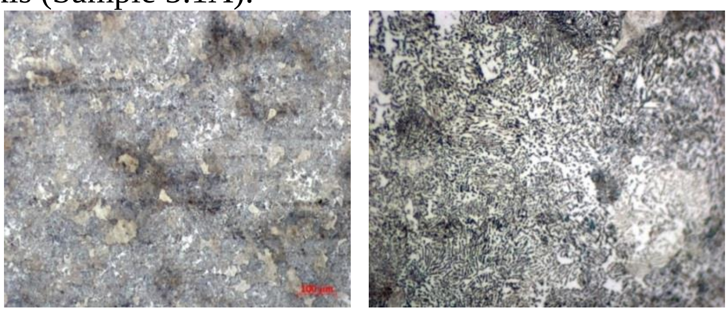
Sample name	Average hardness, HV10	Toughness and shock, J/cm^2
(axial sample)	151	-
(glass directed sample)	156	68.2; 66.3; 71.6

Test result of material organization (micro organizations) in two perpendiculars, in details: Figure 4.3 is image of micro-workpiece organization by vertical axis (Sample 5.1B); Figure 4.4 is image of micro-workpiece organization in perpendicular to axis (Sample 5.1A).



a) 100x b) 500x

Figure 4.3. Image of microorganism organization along the axis (Sample 5.1B)



a) 100x b) 500x

Figure 4.4. Image of microorganism organization perpendicular to the axis (Sample 5.1A)

4.1.2. Equipment used eexperimental process

- 2KHz medium frequency heating equipment (MAG-M-300KW) is used to heat workpieces before hot deformation shaping.
- Measuring equipment, temperature test Sonel DIT-500 measuring range from -50 ÷ 1200^0C of Sonel.
- Vertical type hydraulic press machine CTP250 nominal pressure P = 250 tons of ZDAZ RD1 - Old Czechoslovakia to squeeze back to create detailed Figure.
- Horizontal shaft type hydraulic press CTQ250 with a capacity of 250 tons of ZDAZ - Czechoslovakia to stamp out products after backward extrusion.

In order to carry out analysis and evaluation of mechanical properties, structure of materials received after backward extrusion has been tested by advanced equipment to meet standards in field of material research in some rooms, testing center in Vietnam.

4.1.3. Backward extrusion of 30X3MΦ alloy steel in a hot state

From requirement of detailed drawing of body shell of anti-tank rocket as shown in Figure 4.5, after calculating amount of machining surplus, using designing software Inventor, we have backward extrusion detailed dimensions as shown in Figure 3.3b.

Diagram of basic steps of deformation generation process and fabrication of body shell of anti-tank rocket as shown in Figure 4.6.

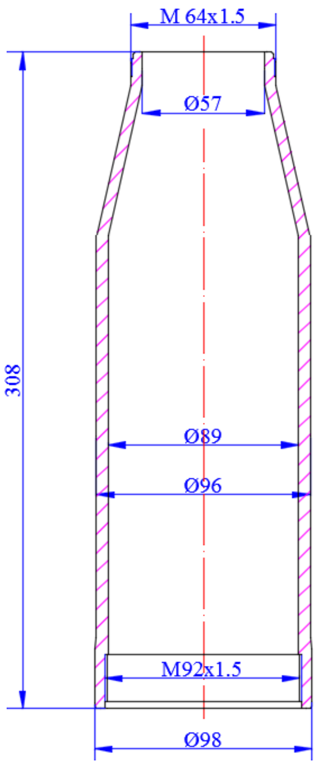


Figure 4.5. Drawing of body shell of anti-tank rocket

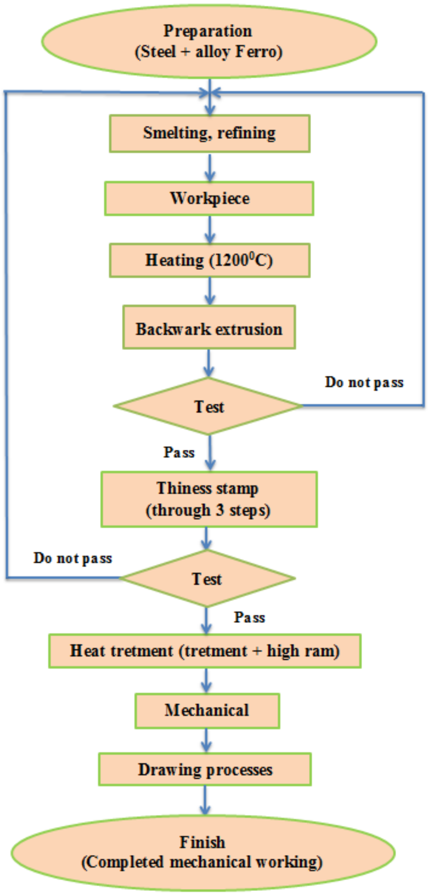


Figure 4.6. Diagram of technical process of manufacturing of body shell of anti-tank rocket

Input workpiece: With detail dimension after extrusion as shown in Figure 3.3b, after adding the residual burnout (1%), using Iventor design software, we have initial workpiece diemention as Figure 3.3a

Steps in backward extrusion of alloy steel 30X3MΦ in hot state

Step 1: From input workpiece as Figure 4.7, proceed to heat workpiece at T = 1200^0 C (Figure 4.8) on frequency heating device MAG - M - 300KW with 8 heating minutes, calcined current intensity I = 100 - 110 (A).

Step 2: Proceed to backward extrusion of workpiece, with time of pressing for 2 seconds for the entire extrusion process (since pestle starts to touch the workpiece until the pestle stops), stable pressure remains at 220 tons (Figure 4.9).

Step 3: Remove workpiece from mold and allow it to cool off the air. Figure 4.10, Figure 4.11 is product after backward extrusion (Φ117x275mm). This product is used as an workpiece for further clawing processes in a technology diagram for the production of body shell of anti-tank rocket.

Figure 4.7. Image of input workpiece (Φ106x120mm)

Figure 4.8. Image of workpiece heating Before backward extrusion

Figure 4.9. Backward extrusion

Figure 4.10. Image of workpiece after backward extrusion

Figure 4.11. Product of backward extrusion (Φ117x275mm)

4.2. Evaluation and discussion of received results after test

4.2.1. Test results on workpiece after backward extrusion

The following product is melted back to cut the Sample to conduct mechanical tests and take photos of microscopic organization:

- Figure 4.12 is the Sample cutting position to test the mechanical properties on the product after extrusion
- Figure 4.13 is a diagram of sample taking positions to take photos of microorganisms

Figure 4.12. Cutting position to test mechanical properties

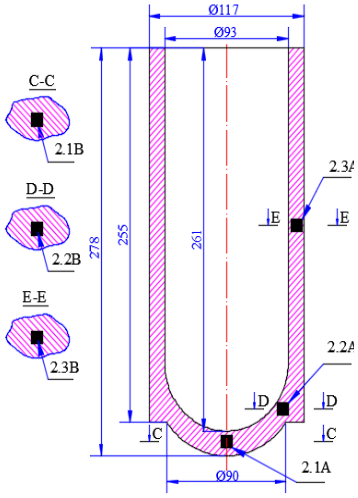


Figure 4.13. Diagram of sampling position to take photograph

Carry out a mechanical test of material on detail after backward extrusion and results are given in Table 4.6

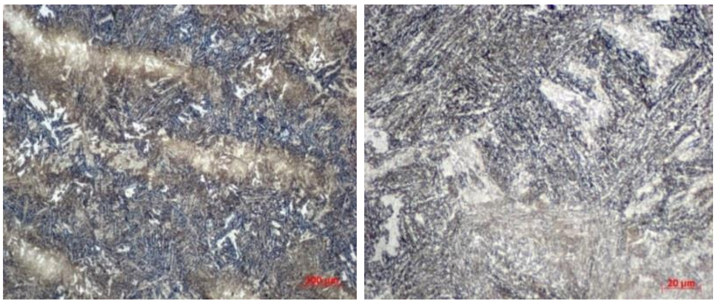
Table 4.6. Mechanical properties on backward extrusion workpiece

Sample name	Yield strength σ_c, MPa	Ultimate Strength σ_b, MPa	Elongation δ, %	Tightening φ, %	Everage hardness, HV_{10}	Stiffness and shock J/cm^2
Φ106x275	1049	1205	14	-	381; 385	16,4

Analysis of material structure (microscopic organization) in two perpendicular directions:

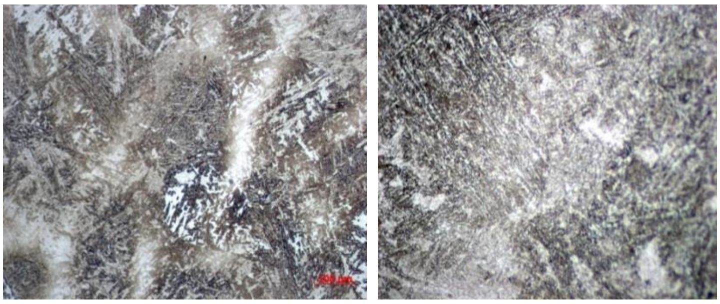
+ Figure 4.14, Figure 4.15, Figure 4.16 are microscopic organization images of Sample on the axial backward extrusion (as shown in Figure 4.13, at positions 2.1A; 2.2A; 2.3A).

+ Figure 4.17, Figure 4.18, Figure 4.19 are the micro organizational figures of Sample on the reciprocating presses perpendicular to the axis (as shown in Figure 4.13, at positions 2.1B; 2.2B; 2.3B)



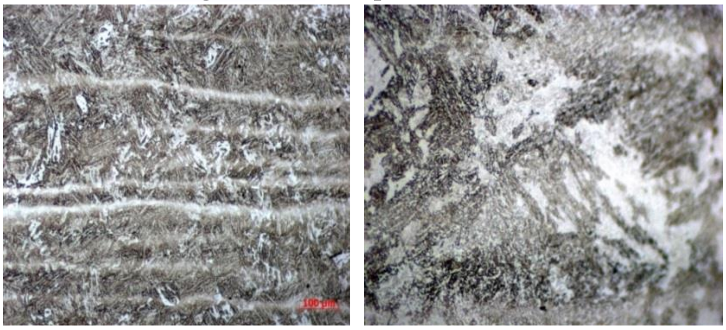
a) 100x b) 500x

Figure 4.14. Image of microorganism organization along the axis , at position 2.1A



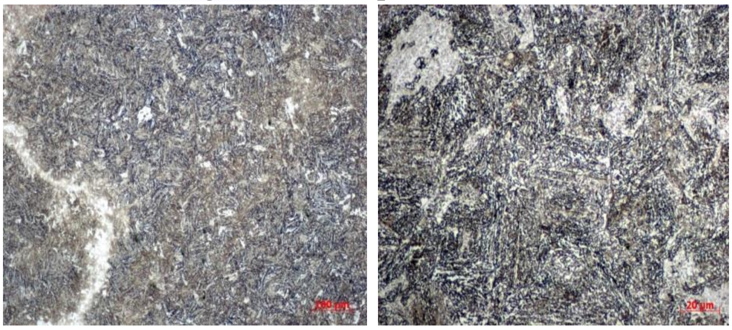
a) 100x b) 500x

Figure 4.15. Image of microorganism organization along the axis , at position 2.2A



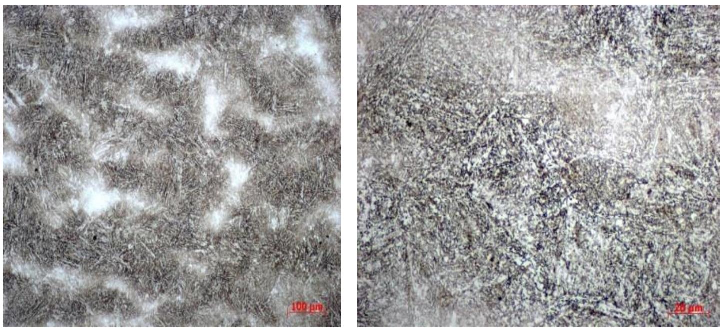
a) 100x b) 500x

Figure 4.16. Image of microorganism organization along the axis , at position 2.3A



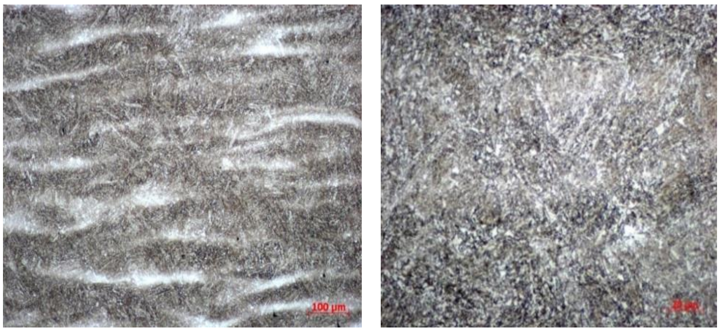
a) 100x b) 500x

Figure 4.17. Image of microorganism organization along the axis , at position 2.1B



a) 100x b) 500x

Figure 4.18. Image of microorganism organization along the axis , at position 2.2B



a) 100x b) 500x

Figure 4.19. Image of microorganism organization along the axis , at position 2.3B

4.2.2. Discuss achieved results for input workpiece

With achieved chemical composition (table 4.3), chemical composition of material in thesis is equivalent to chemical composition of steel 30Х3МФ (according to ГОСТ 4543-71).

With measured mechanical properties in two perpendicular directions as shown in Table 4.4 and Table 4.5, it is found that this is cast steel and only recently processed preliminary forging, mechanics is still not high, but is suitable with properties of cast steel materials in general.

Figure 4.3 and Figure 4.4 are images of microscopic organization on input workpieces: along the axis and perpendicular to the axis. Though those images with different magnifications, we find that micro-organization of casting steel material consists of phases, spherical shaped particles, multi-edge particles with a relatively small and smooth size and even dispersion. Material organization arrangement is relatively homogeneous, or same microorganism is organized in perpendicular directions in object.

Mechanical properties of materials: cast alloy steel (not underwent preliminary heat treatment) has yield strength, ultimate Strength; stiffness, as shown in Table 4.4 and Table 4.5 in two perpendicular directions with similar values combined with aforementioned microorganism analysis, showing that input material is highly isotropic.

4.2.3. Discuss on achieved results for workpiece ater extrusion

a) About mechanical properties of material

From test results of yield strength and stiffness of workpiece after backward extrusion in Table 4.6, we have:

- Yield strength of backward extrusion workpiece σ_c = 1049MPa, this limit is 2.98 to 3.15 times higher than that of input workpiece.
- Yield strength of backward extrusion workpiece σ_c = 1205MPa, this limit is 2.08 to 2.14 times higher than that of input workpiece.
- Stiffness on workpiece in backward extrusion is according to Table 4.6, averaging from 381 to 385 HV, 2.44 to 2.54 times higher than stiffness on input workpiece (Table 4.5).

b) Regarding micro-organization of materials

Figure 4.14, Figure 4.15, Figure 4.16 is microscopic organization on workpieces after backward extrusion along the axial at three different positions, found: The organization is arranged in orientation, ie grain organization, strip and showed gradually from bottom position to finished position.

- At bottom position of workpiece, direction of grain has arranged along axial direction but this position is not clear at two perpendicular sections (ie Figure 4.14 and Figure 4.17).
- At side position (transition zone), there is a clearer difference between two positions: axial position (Figure 4.15) and perpendicular to the axis (Figure 4.18). The grain organization, bands on Figure 4.15 (ie 2.2A position) was easily observed by deformation. In this way, mactenxit and austenite particles with a deformed effect have been flattened, elongated to create grain and banding fringes, while at the perpendicular cutting plane Figure 4.18, we almost do not observe this organization.
- At position on wall, material grain organization is most clearly shown. According to rolling direction in Figure 4.16, particles are deformed, elongated and flattened. In perpendicular direction of rolling Figure 4.19, we can not observe organization of band and grain of material, this organization is still:

mactenxit background with a dark-colored shape surrounded by residual austenite particles in light color with other cacbit which is evenly distributed, smooth on that background. Figure 4.16a show that deformation in crystal is caused by sliding mechanism (slip marks) as studied theory of metal plastic deformation.

Thus, after backward extrusion, organization receives deformed martensite particles and deformed austenite particles, flattened and elongated particles along deformation along with small and fine-dispersed carbide components.

4.3. Application of details after backward extrusion to manufacture body shell of anti-tank rocket

After backward extrusion, tube-shaped parts meet the technical requirements, making body shell of anti-tank rocket through two elements of deformation: stroking work and mouth (claw) and mechanical working to finish products.

4.3.1. Stroking work:

Stroking process is carried out through three steps on stamping machine as horizontal as Figure 4.20, stroking temperature T = 1200^0C. At the end of the three-step stroke process, we get product as shown in Figure 4.21, with the size Φ102x380mm.

Figure 4.20. Image of stroking process

Figure 4.21 Product after stroking

4.3.2. Deforming and mouth (stroking) for product

After being troking in aforementioned three-step, product is well heat-treated (treatment + high ram), ensuring nnecessary mechanical properties for the fabrication of body shell of anti-tank rocket, undergoing mechanical processing step 1 (rough machining) as shown in Figure 4.22 to serve the deformation - mouth. Carry out the deformation - detailed mouth, we get details after this process as Figure 4.23.

Figure 4.22. Image of workpiece after mechanical working to support mouth deformation

Figure 4.23. Image of workpiece after mount deformation

4.3.3. Mechanical working and product finishing

The tube part after deformation - mouth opening, is processed to complete the product as shown in figure 4.24

Figure 4.24. Image of product after completed mechanical working

Figure 4.25. Image of body shell of anti-tank rocket after heating testt

After checking the microstructure, body shell is put to pressure test to check bark durability (static test), the test pressure of 65MPa meets the requirements for painting. Next, the product will be tested for engine combustion to check the housing durability as shown in Figure. The process of conducting combustion tests as shown in Figure 4.25, satisfactory results, body shell of anti-tank rocket are not stretched, cracked, pressure curve equivalent to that of Russian bullets.

CONCLUSION CHAPTER 4

The results of research on experimental process of backward extrusion of alloy steel in hot state draw some following conclusions:

- The cast alloy steel workpiece (electroslag + forged) is made in the country as the input workpiece for the backward extrusion equivalent to steel 30X3M (according to 45CT 4543-71), which is isotropic, ensuring love technical demand.

- Pipe details after mechanical backward extrusion have mechanical and organizational properties to ensure technical requirements for manufacturing of body shell of anti-tank rocket:

+ Mechanical properties of the material greatly increased after backward extrusion: Yield strength σ_c = 1049MPa is 2.98 8 higher than 3.15 times; ultimate strength σ_b= 1205MPa is higher than 2.08 ÷ 2.14; The average stiffness is from 381 ÷ 385 HV, 2.44 ÷ 2.54 times higher than input workpiece. This proves that the phenomenon of material duration in backward extrusion in hot state occurred.

+ The microcrystalline organization received after backward extrusion has changed organization from peclit + ferit to mactenxit ram + residual austenite, fine small particles in both axial directions and perpendicular to axis, told to make input workpiece for manufacturing body shell of anti-tank rocket.

- Product of body shell of anti-tank rocket after fabrication by backward extrusion technology from cast steel to test the technical requirements and the pressure test reached 65MPa, try to burn satisfactory.

- Selecting experimental equipment, testing equipment to ensure accuracy, meet technical requirements, building a diagram of the process of manufacturing pressure-resistant pipe technology to produce suitable body shell of anti-tank rocket for domestic conditions.

CONCLUSION AND RESEARCH METHODS IN THE FUTURE

From the research contents and the results achieved in the thesis, make the following conclusions:

1. Research application of backward-pressing base theory to produce high strength low alloy steel tubular details. Combining theoretical research with numerical simulation and experimentation are to define the technological parameters for backward-forming presses for fabricating tubular details under pressure to replace steel workpieces.

2. By numerical simulation, it is possible to define the appropriate temperature (T = 1200^0C) for extrusion process, as a basis for experimental process of backward extrusion of hot-alloyed steel.

3. Determine the size of the bridge radius (R) of workpiece face, instead of workpiece with a conical Figure cone as the actual production, reducing the error rate in the backward extrusion.

4. Develop a digital simulation math, through the simulation data processing, gave the following results:

- Provide the rule of distribution of stress, deformation and graph of pressure distribution in backward extrusion. Determine appropriate working area of ratio (d/D) and (H/D) as basis for the experimental process, specifically:

+ When pressed at a variable level, ratio d/D = 0.77; 0.81 can be pressed with height H/D $\leq$ 3.6 times.

+ When the thinning level is pressed, the ratio of d/D = 0.85 occurs with workpiece destruction (at 8%) during the survey.

+ When pressing at level of d/D = 0.89 $\div$ 0.93, there is a phenomenon of "stress concentration", enlarged dead zone. This indicates that thinning at thinning level to d/D = 0.89 $\div$ 0.93 is not appropriate.

- Having built functions and graphs representing the relationship between (d/D); (H/D) with the highest degree of equivalent deformation and the greatest pressure. From equations, graphs allow to assess the influence of the ratio (d/D); (H/D) to the degree of equivalent deformation and maximum average pressure.

5. Through empirical research, the results are as follows:

- Research results of cast steel workpiece (ingot input) manufactured in country show that materials have high isotropic, mechanical properties and organization to ensure technical requirements to serve the process of backward extrusion of pressure pipe details.

- Experimental results of backward extrusion showed that the mechanical properties of the material increased much (durable limit increased to 2.14 times; average hardness of HV increased to 2.54 times); there has been a change in organization from Perlit + Ferit to Martenite Ram + anustenite organization. It is demonstrated that chemical duration phenomenon in backward extrusion of alloy steel in hot state.

6. Materials 30CrMoNi5 and cast alloy steel (equivalent to steel 30X3MΦ) made in Vietnam have similar reaction at 1200^0C. This reseach result can be applied to similar high strength low alloy steel.

7. Results of empirical research on backward extrusion technology are used to manufacture body shell of anti-tank rocket, confirming proactive ability in production to create pressure tube shaped details in Vietnam.

Research methods in the future

1. Research causes and destruction mechanism of workpiece in backward extrusion of high strength low alloy steel.

2. Study origin and organization of material after backward extrusion.

LIST OF PUBLIC WORKS

1. MSc. Bui Khac Khanh, Dr. Vu Trung Tuyen, MSc. Nguyen Truong Huy, MSc Le Van Thoai (2016), *A research on manufacturing technology body shell of anti-tank rocket R122*, Vietnam mechanical journ No. 12, page 40-44.

2. Nguyen Ha Tuan, Bui Khac Khanh, Vu Trung Tuyen, Nguyen Truong Huy, Vi Thi Nhung (2018),

Research steel refining technology 30X3MΦ from scrap steel to manufacture body shell of anti-tank rocket, Journal Metal Science and Technology No. 77, pages 37-42

3. Bui Khac Khanh, Nguyen Ha Tuan, Vu Trung Tuyen, Pham Van Nghe (2018), *Research impact of ratio d/D and H/D on tube detail shaping process during backward extrusion of alloy steel in hot state by digital simulation*, Vietnam Mechanical Journal No. 10, page 70-77.

4. Bui Khac Khanh, Nguyen Ha Tuan, Vu Trung Tuyen, Nguyen Truong Huy (2019), *A research on manufacturing technology body shell of anti-tank rocket*, Applied Mechanics and Materials, Vol. 889, PP. 131-139. (The draft has been repored and posted in the Internation Conference (2018), “The First International Conference on Material, Machines and Methods for Sustainable Development”, Pages 996-1003).