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Identification of the Distribution of Muzzle Velocity and Maximum Pressure in the Barrel for a Typical Rifle

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ABSTRACT: The paper presents the procedure for identifying the distribution of muzzle velocity and the maximum pressure in the barrel for a typical 7.62mm rifle. Input data are collected through the experiment using 50 shots for muzzle velocity and 20 shots for maximum pressure. The distribution is identified with the support of Minitab software. Research results show three distributions suitable with muzzle velocity and maximum pressure in the barrel: the normal, 2P-Weibull and 3P-Weibull. Among them, the 3P-Weibull distribution is best suited to the muzzle velocity and the normal distribution is best suited to the maximum pressure in the barrel. The research results of the paper will help reduce the number of experiments when determining the muzzle velocity and the maximum pressure of the rifle.

KEYWORDS: Muzzle velocity; Pressure in the barrel; Normal Distribution; Weibull Distribution; Rifle; 7.62x39mm ammo.

I. INTRODUCTION

The muzzle velocity and maximum pressure in the barrel are essential parameters when studying, designing, and using weapons. These are also two parameters studied in many published weapons and ammunition research works. However, identifying the distribution of muzzle velocity and maximum pressure is still a new research issue.

The publications [1] study the prediction of internal pressure distribution and muzzle velocity in the rifled barrel of a light weapon. In this work, the object search consists of NATO standard small calibre barrels of 7.62 mm and 5.56 mm in diameter. Internal pressure distributions and projectile velocities were experimentally measured as functions of time and displacement. And then using the curve-fitting method to define a function of a projectile velocity. Park, Sung-Ho et al. [2, 3] investigate the statistical distribution of muzzle velocity of 155mm propelling charge K676 for using K9, a Korean 155mm self-propelled artillery. Kim, Jaekab, and Jaehoon Kim [4] also confirm the change of muzzle velocity and the most suitable probability distribution model of the 155 mm K9 howitzer barrel with chrome plating and changed rifling. Besides, the publications [5] predict the distribution of the cylinder inner diameter and the piston outer diameter post-manufacture for gas-operated automatic rifles. Besides, the influence of these dimensions on the operation of the automatic system was also studied in 5 cases with the maximum, minimum, and most probable. It can be seen that the research objects of [2, 3, 4] are all 155m K9 artillery without researching rifles.

So, identifying the distribution of muzzle velocity and maximum pressure in the barrel for rifles is still a new research problem that needs to be researched. In order to contribute to this problem, the article presents a process research to define the distribution of muzzle velocity and maximum pressure in the barrel for a typical 7.62mm rifle when firing 7.62x39mm ammo.

This paper is organized as follows: The first section serves as an overview. Section 2 illustrates the theoretical basis and experimentation. Section 3 describes the experimental process. Section 3 gives results and discussion. Finally, section 4 summarizes some significant results.

II. THEORETICAL FOUNDATIONS AND EXPERIMENTATION

A Theoretical foundations

In probability theory and statistics, the characteristic function of any real-valued random variable ultimately defines its probability distribution. There are many different distributions, such as Degenerate, Bernoulli, Binomial, Negative binomial, Poisson, Uniform (continuous), Uniform (discrete), Laplace, Logistic, Normal, Chi-squared, Cauchy, Gamma, Exponential, Geometric, Multivariate normal, Multivariate Cauchy, Weibull [6, 7, 8, 9]. In order to predict the distribution of random data, there are also many different methods. Using software to support distribution prediction is a widely used method. The Minitab software is a handy tool that allows you to quickly compare how well your data fits different distributions [10]. Before we walk through the output, three measures need to be known: Anderson-Darling statistic (AD), P-value and LRT P.

Anderson-Darling statistic (AD): Lower AD values indicate a better fit. However, to compare how well different distributions fit the data, it should assess the p-value.

P-value: It is generally valid to compare p-values between distributions and go with the highest. A low p-value indicates that the data do not follow that distribution. For some 3-parameter distributions, the p-value is impossible to calculate and is represented by asterisks.

LRT P: For 3-parameter distributions only, a low value indicates that adding the third parameter is a significant improvement over the 2-parameter version. A higher value suggests that you may want to stick with the 2-parameter version.

B Experiment preparation

In order to predict the distribution of muzzle velocity and maximum pressure in the barrel, the first step is to collect the values of these quantities from the experiment. The experiment was conducted at the Weapon Technology Center of Le Qui Don University.

1) Measurent the muzzle velocity: The experimental subjects were 7.62x39mm ammo fired from a 7.62mm rifle AKM with a barrel length of 415m. The experimental scheme is shown in Figure 1. The DRS-1 radar Doppler system is used to measure the muzzle velocity. The muzzle velocity obtained after 50 shots is shown in Table 1. The histogram graph of muzzle velocity is shown in Figure 2.

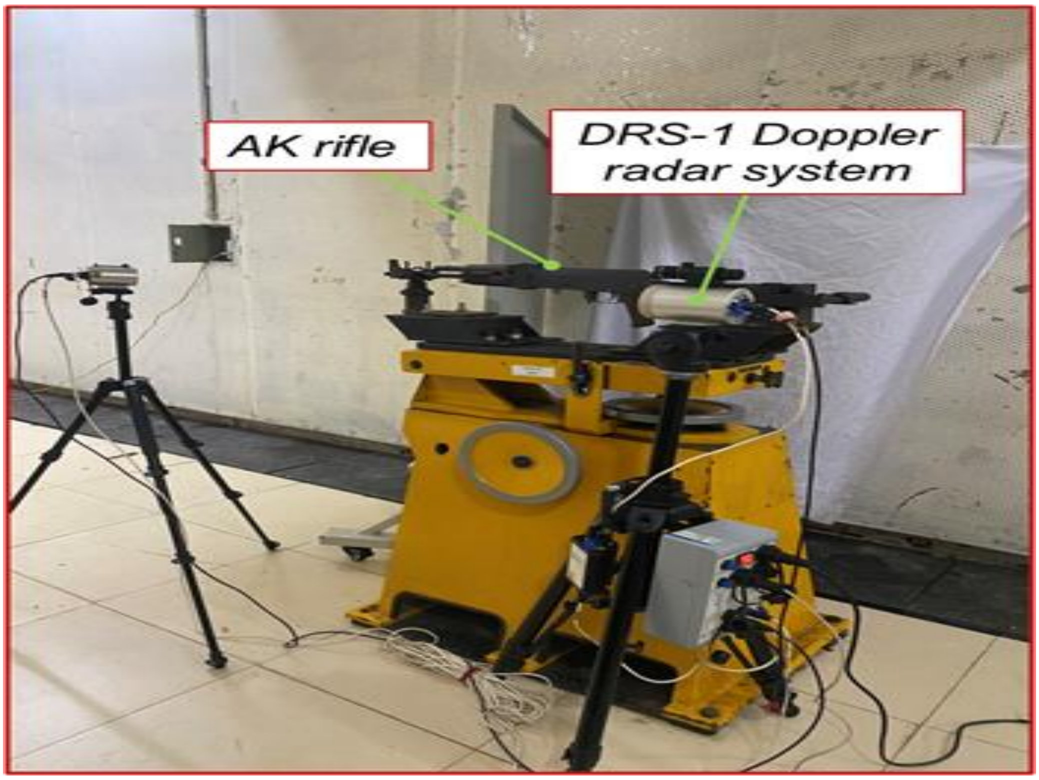

Figure 1. The experimental scheme measures the muzzle velocity

Table 1. Bullet velocity at the muzzle of 50 shots

Shot No.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Muzzle velocity (m/s)	719	725.2	720.9	714.3	708.6	724.9	708.4	703	715.2	713.3
Shot No.	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Muzzle velocity (m/s)	710.9	709.7	705.7	713.1	708.4	717.5	708.4	709.7	713.9	714.4
Shot No.	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
Muzzle velocity (m/s)	701.4	718.1	719.1	717.5	716.6	710.3	719.9	714.8	716.2	714.1
Shot No.	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**
Muzzle velocity (m/s)	717.5	716.6	714.4	717.4	717	701.4	713.2	712.9	714.7	713.6
Shot No.	**41**	**42**	**43**	**44**	**45**	**46**	**47**	**48**	**49**	**50**
Muzzle velocity (m/s)	723.7	710.8	717.4	721	720.1	716.3	707.9	709.6	711.3	712.7

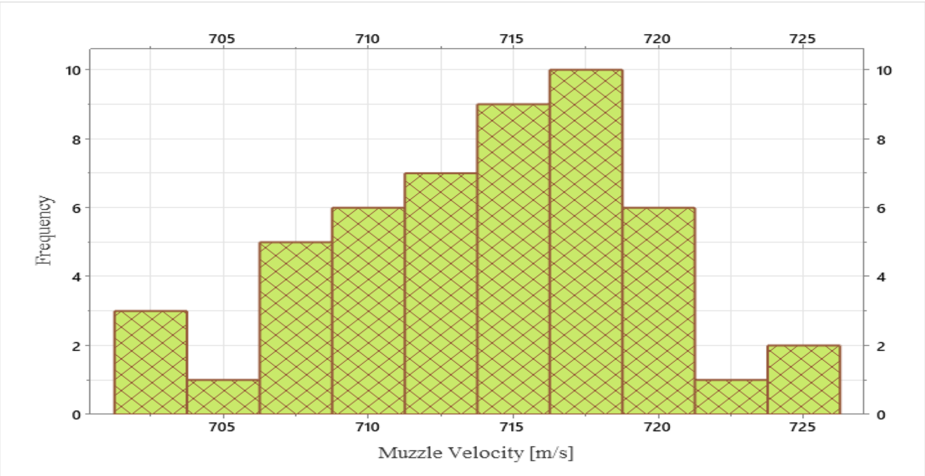

Figure 2. Histogram of Muzzle Velocity

Table 2. Maximum pressure in the barrel of 20 shots

Shot No.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Maximum pressure (MPa)	266.453	259.747	281.661	252.136	247.257	252.253	272.326	275.525	258.433	272.326
Shot No.	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Maximum pressure (MPa)	233.921	274.139	246.438	238.309	257.493	233.018	248.245	231.211	251.17	247.299

2) Measurent the maximum pressure in the barrel: The experiment to measure the maximum pressure inside the barrel was conducted using a 7.62x39mm ballistic barrel. There are many methods to measure the maximum pressure inside the barrel, and this paper uses an electronic piezoelectric. The DEWE Software is used to analyze the obtained values. The process of this experiment is shown in Figure 3. The values obtained after 20 shots are shown in Table 2. The histogram graph of muzzle velocity is shown in Figure 4.

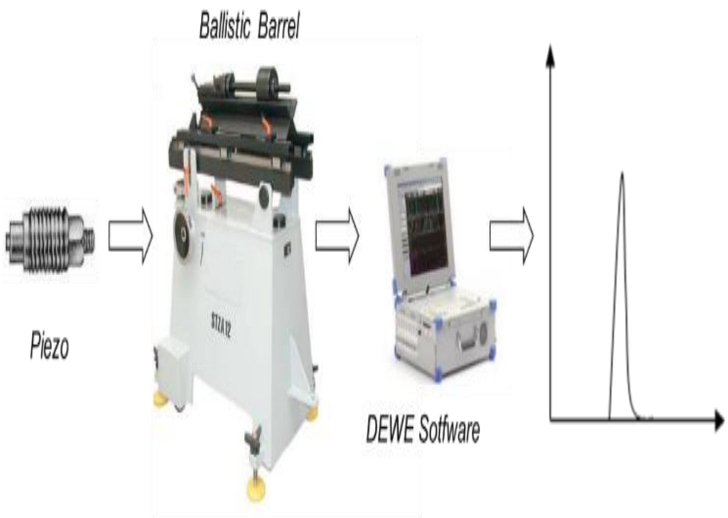

Figure 3. The process of Measurent the maximum pressure in the barrel

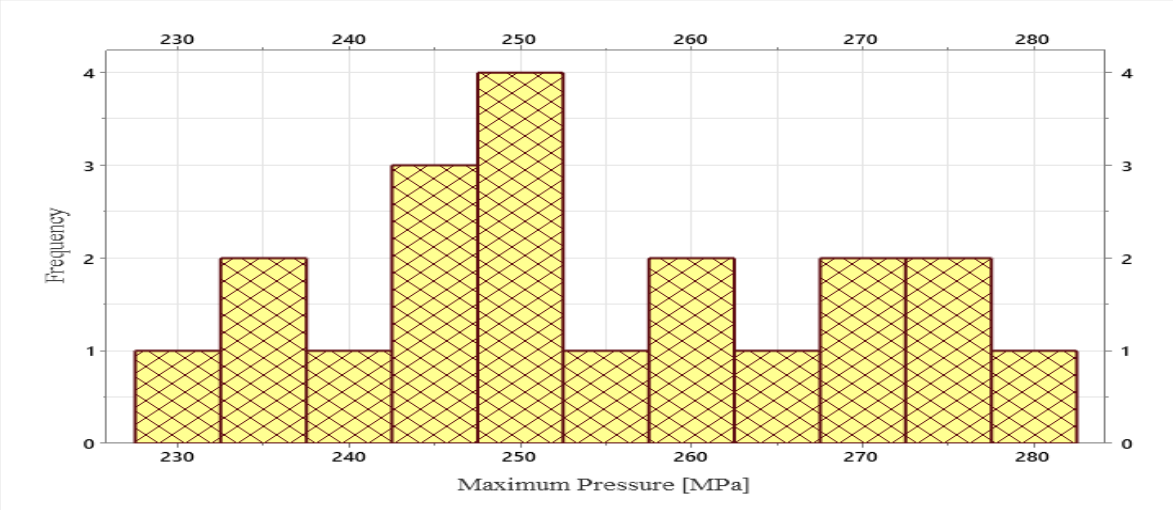

Figure 4. Histogram of Maximum Pressure

III. RESULTS AND DISCUSSION

A Identification of the distribution of muzzle velocity

After collecting data such as Table 1, use Minitab software to analyze and predict the distribution of muzzle velocity. The analysis results indicate that three distributions are suitable for the muzzle velocity distribution: Normal, 2P-Weibull, and 3P-Weibull (Figure 4, Table 3, Table 4). However, when we analyzed these distributions, we found that if we consider the AD value, the 3P-Weibull has the highest value. The P-value of this distribution is also greater than 0.5 (much more significant than 0.05). In addition, the LRT P value is 0.044. Therefore, the 3P-Weibull distribution is the most suitable for muzzle velocity among these three distributions. The probability density function (PDF) for Normal, 2P-Weibull, and 3P-Weibull distribution of muzzle velocity is shown in Figure 5 and Figure 6

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Table 4. Goodness of Fit Test for Muzzle Velocity

Distribution	**AD**	**P**	**LRT P**
Normal	0.295	0.584	
Weibull	0.552	0.164	
3-Parameter Weibull	0.256	>0.500	0.044

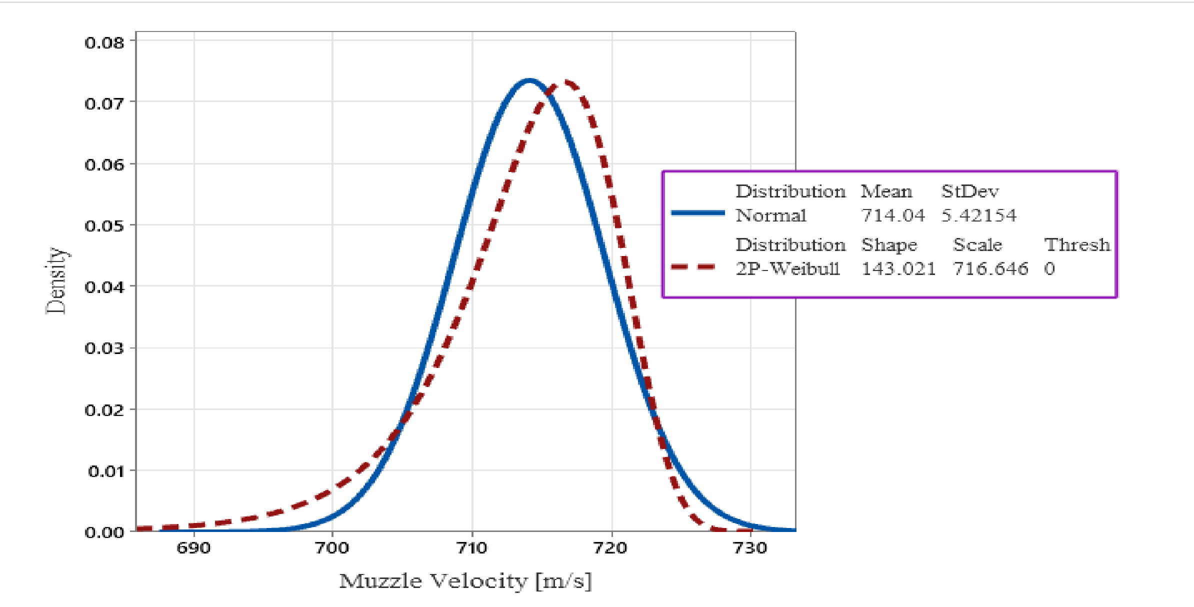

Figure 5. Probability density function (PDF) for Normal, 2P-Weibull distribution of muzzle velocity

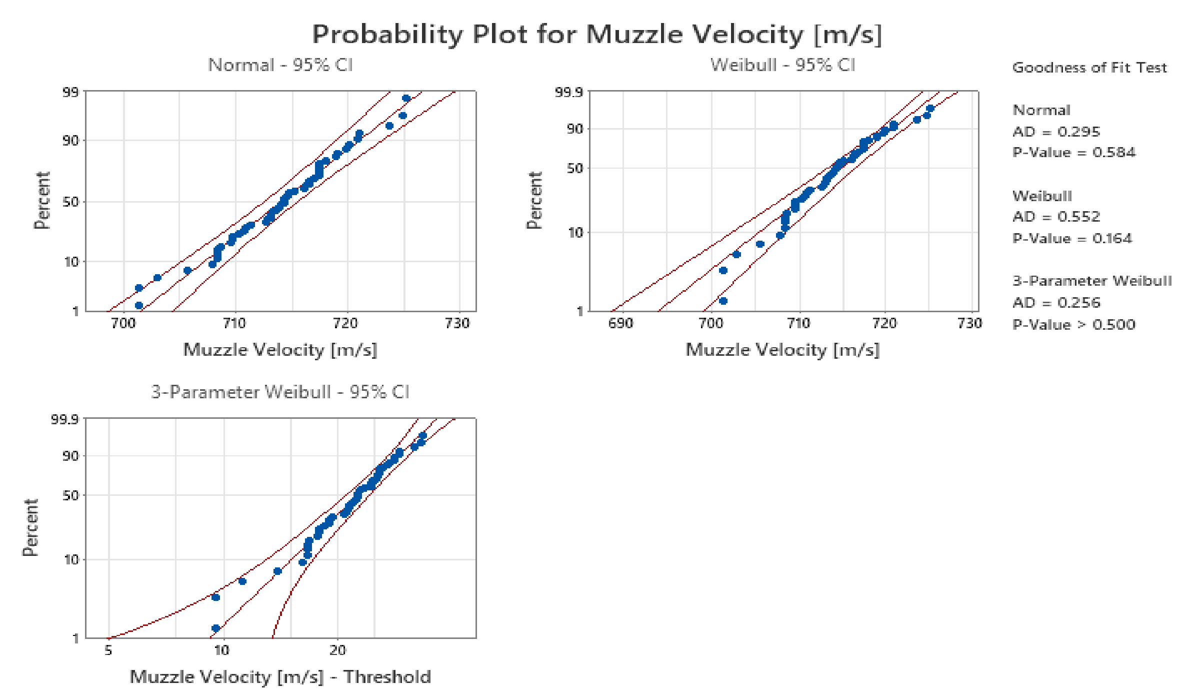

Figure 4. Probability plot of muzzle velocity for Normal, 2P-Weibull and 3P-Weibull distributions

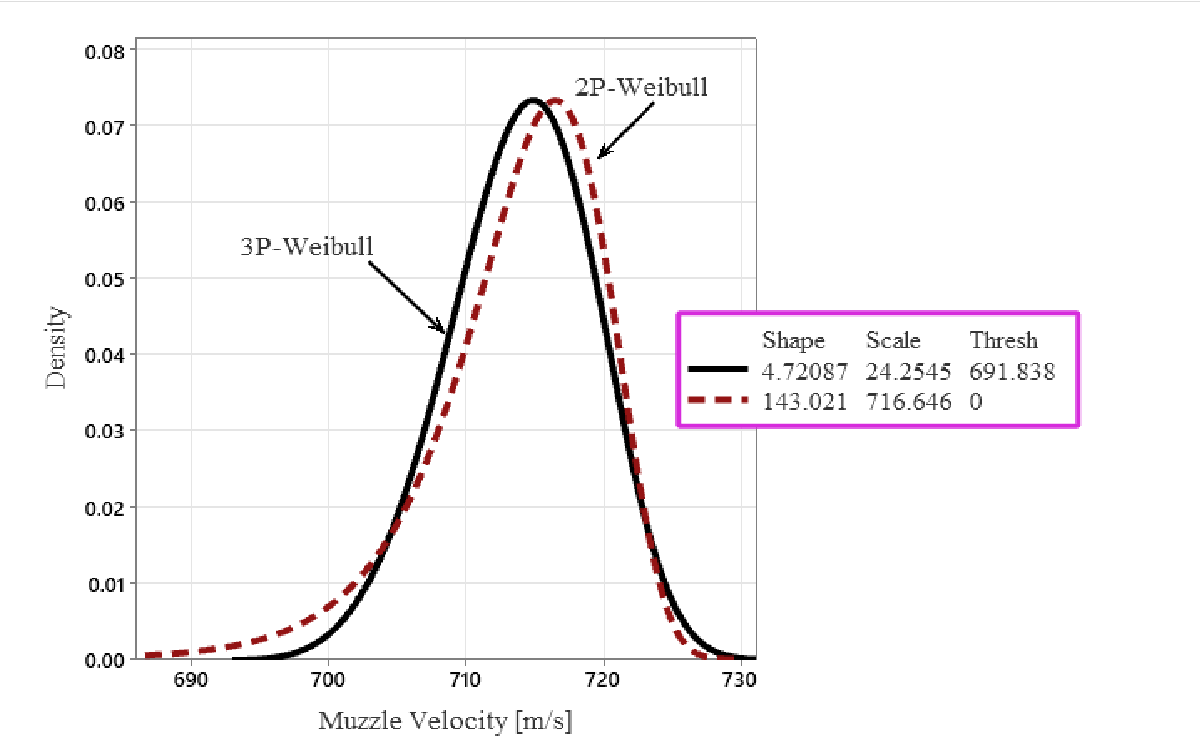

Figure 6. Probability density function (PDF) for 2P-Weibull, 3P-Weibull distribution of muzzle velocity

B Identification of the distribution of maximum pressure

Using the same procedure as the muzzle velocity, we also get three distributions suitable for the maximum pressure in the barrel: Normal, 2P-Weibull, and 3P-Weibull distributions. The probability graph of maximum pressure is shown in Figure 7. The statistical values are listed in Table 5. The AD, P-value and LRT P values correspond to the distributions as in Table 6. When considering these three distributions, we see that the AD value of the Normal distribution is the smallest (0.331), while the P value is the largest (0.485). Therefore, it can be concluded that the Normal distribution is the most suitable for the maximum pressure in the barrel.

The probability density function (PDF) for Normal and 3P-Weibull distribution of maximum pressure is shown in Figure 8.

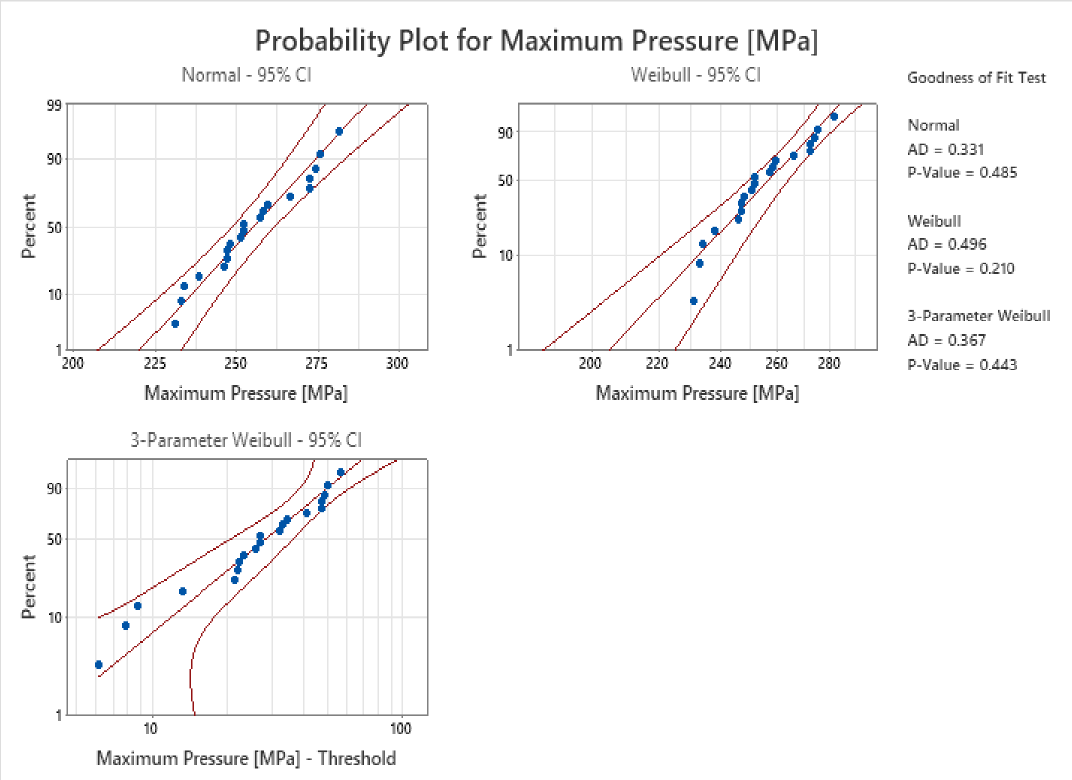

Figure 7. Probability plot of maximum pressure for Normal, 2P-Weibull and 3P-Weibull distributions

Table 5. Descriptive Statistics for Maximum Pressure

N	N*	Mean	StDev	Median	Minimum	Maximum	Skewness	Kurtosis
20	0	254.968	15.0632	252.194	231.211	281.661	0.120324	-0.929953

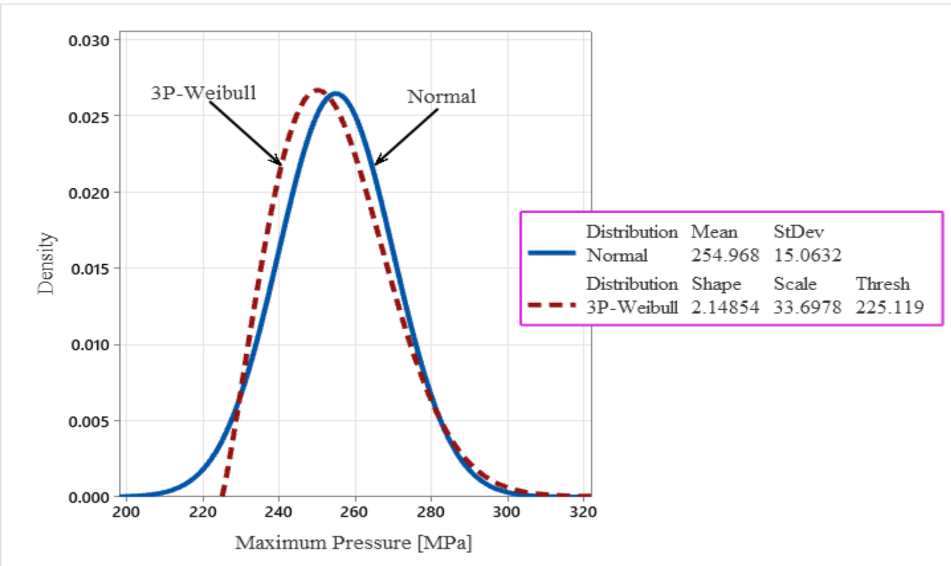

Figure 8. Probability plot of maximum pressure for Normal, 3P-Weibull distributions of Maximum pressure

Table 6. Goodness of Fit Test for Maximum Pressure

Distribution	AD	P	LRT P
Normal	0.331	0.485	
Weibull	0.496	0.210	
3-Parameter Weibull	0.367	0.443	0.100

IV CONCLUSION

The distribution of muzzle velocity and maximum pressure in the barrel is a new research issue, and it is studied in the present study. The calculation process is carried out for the 7.62mm typical rifle firing 7.62×39 mm ammo. Based on the analysis obtained in the calculation results, some of the main highlights can be summarized below:

(1) The distribution of muzzle velocity and maximum pressure in the barrel can be described by one in three distributions: Normal distribution, 2P-Weibull distribution, and 3P-Weibull distribution.

(2) The 3P-Weibull distribution is most suitable for describing the distribution of muzzle velocity, while the normal distribution is most suitable for maximum pressure.

Future research will focus on the identification of another parameter for differential weapons.

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