SOI: 1.1/TAS DOI: 10.15863/TAS

International Scientific Journal

Theoretical & Applied Science

p-ISSN: 2308-4944 (print) **e-ISSN:** 2409-0085 (online)

Year: 2026 **Issue:** 10 **Volume:** 162

Received: 29.10.2026
Accepted/Published: 30.10.2026 https://T-Science.org

Issue Article

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SPATIOTEMPORAL DYNAMICS OF BTF EXPLOSION FRONT PROPAGATION

Abstract: *The article examines the spatiotemporal evolution of the computed pressure field during the propagation of an air shock wave initiated by a BTF explosion. Based on three-dimensional visualization, the propagation of the shock wave front from a source located at the origin and the variation in pressure with distance were analyzed. It was established that, by the end of the time interval considered, the shock wave front had reached a distance of approximately 80-100 m. Its propagation was accompanied by a decrease in velocity, while pressure diminished with increasing distance from the source. To quantify the radial dynamics of the shock wave front, the data were fitted with the power-law relation* $R(t) = 1.761428t^{0.85285}$, *where the radius is expressed in metres and time in milliseconds. The coefficient of determination in logarithmic space was* $R^2_{log} = 0.959086$. *An exponent below*

unity indicates sublinear growth in the radius over the time interval investigated. The resulting model can be used as a compact approximation for interpolating the position of the shock wave front under the conditions considered.

***Key words**: BTF explosion, shock wave, computed pressure field, shock front radius, power-law approximation, spatiotemporal dynamics.*

***Language**: English*

Citation: Chemezov, D., et al. (2026). Spatiotemporal dynamics of BTF explosion front propagation. *ISJ Theoretical & Applied Science, 10 (162),* 68-71.

Soi: https://s-o-i.org/1.1/TAS-10-162-11 ***Doi***: https://dx.doi.org/10.15863/TAS.2026.10.162.11

***Scopus ASCC**: 2211.*

1. Introduction

In this work, BTF refers to benzotrifuroxan, an energetic compound whose detonation produces explosion products and a pressure wave that propagates through the surrounding medium. Research on BTF encompasses the experimental determination of detonation and explosion product parameters [1], the distribution of electrical conductivity in the detonating material [2], and the investigation of the properties of BTF and its mixtures [3-10].

However, the studies considered primarily focus on the properties of the explosive itself and on detonation processes. A quantitative description of the radial propagation of the pressure front over time (particularly, an assessment of the power-law growth of its radius) remains insufficiently addressed. The aim of this study is to analyse the calculated spatiotemporal pressure field generated by a BTF explosion and to approximate the relationship between the pressure front radius and time using a power function.

2. Materials and methods

The study investigated the propagation of the pressure wave generated by the initiation of a BTF explosion in an air domain. The analysis was based on calculated pressure fields presented as three-dimensional spatiotemporal visualisations. The explosion source was located at the origin of the coordinate system, allowing the position of the shock wave front to be described relative to a common reference point.

In the visualisation, the spatial coordinates represented the field's position relative to the source, while the vertical axis represented time. Accordingly, it was interpreted as a temporal coordinate rather than as a spatial height. The colour field represented pressure magnitude on a logarithmic scale. This representation was used to clearly illustrate the spatial distribution of pressure and its evolution over time.

To quantitatively characterize the propagation of the shock wave, the radius R of its front was determined at successive time points t. The radius was defined as the distance from the source, located at the origin of the coordinate system, to the position of the shock wave front at the corresponding time. Time was expressed in milliseconds (ms), and the radius in meters (m). Thus, the dynamics of the shock wave front were described by the function of $R(t)$.

For each time point considered, the distance from the origin to the corresponding boundary of the shock wave front was recorded during data processing. The resulting radius values were correlated with the corresponding time points and used to describe the temporal evolution of the shock wave front's position.

3. Results and discussion

The three-dimensional plot (Figure 1) shows the evolution of the calculated pressure field following the initiation of the BTF explosion. The source is located at the origin, and the wavefront propagates through the air domain. When interpreting the plot, it is important to note that the vertical axis represents the time evolution of the explosion process. The surface represents the spatiotemporal distribution of the computed quantities, rather than an instantaneous profile of the shock wave in physical space.

As time progresses, the shock wave front propagates radially outward from the source, reaching a distance of approximately 80-100 m by the end of the interval considered. The nonuniform displacement of the front indicates a decrease in propagation velocity over time.

The color field represents pressure on a logarithmic scale. The highest values are concentrated near the source; pressure decreases with increasing distance, indicating that the shock wave weakens as it propagates.

A power-law regression was fitted to quantitatively describe the propagation of the front (Equation 1):

$$R(t) = at^b \quad (1)$$

where R is the radius of the front, measured in meters; t is time, measured in milliseconds; and $a = 1.761428$ and $b = 0.85285$. The coefficient of determination for the regression in logarithmic space was $R^2_{log} = 0.959086$.

The parameter b is the exponent that characterizes the dependence of the radius on time. For $b = 1$, the model would describe linear growth in the radius, corresponding to a constant velocity of the shock wave front. The obtained value $b < 1$ corresponds to sublinear growth: the radius increases, while its rate of change decreases over time within the framework of the power-law model.

The coefficient a determines the scale of the relationship and depends on the units of measurement chosen. When t is measured in milliseconds and R in meters, its units are m/ms^b. Therefore, the value of a cannot be interpreted as the propagation velocity of the shock wave front. The coefficient R^2_{log} quantifies the model's goodness of fit to the data after logarithmic transformation. It is not an estimate of the error relative to the physical experiment.

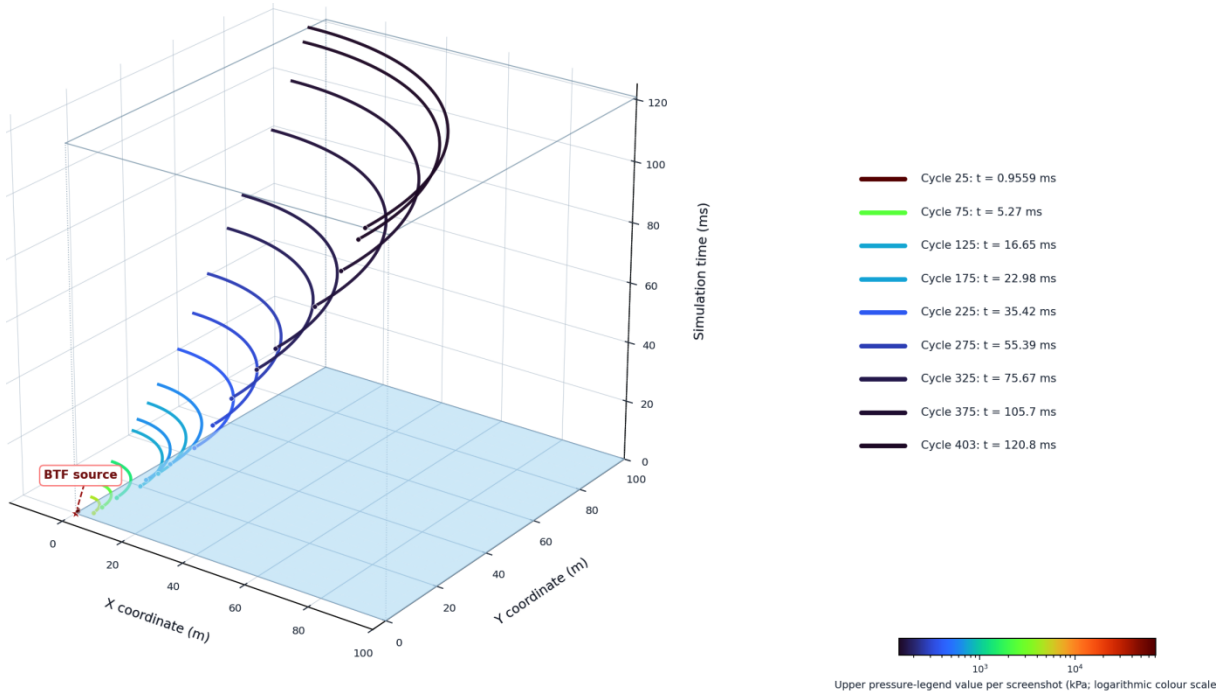

Figure 1. Spatiotemporal evolution of the calculated pressure field following the initiation of the BTF explosion in the air domain.

The analysis presented combines spatiotemporal visualization of the computed field with a preliminary quantitative approximation of the shock wave front radius using a power-law function. This makes it possible to move beyond a qualitative observation of shock wave expansion toward a parametric description of its radial dynamics, while formulating a testable hypothesis that the radius grows sublinearly over the time interval investigated.

The practical significance of this result lies in the potential use of the power-law relationship as a compact approximation for interpolating the shock front radius within the investigated time range and under the conditions of the BTF explosion process.

4. Conclusion

The analysis of the calculated pressure field demonstrates the radial propagation of the BTF explosion front and the attenuation of pressure with increasing distance from the source. The power-law model $R(t) = 1.761428t^{0.85285}$, with a coefficient of determination $R^2_{log} = 0.959086$, characterizes the sublinear evolution of the front radius over the investigated time interval. The resulting relationship can be used to interpolate the shock wave radius under the conditions considered. Its extrapolation requires further validation.

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