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Experimental and Numerical Determination of Riffle Barrel Properties

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Abstract. The paper describes an experimental procedure for determining the properties of a conventional steel barrel. The deformation behavior during shooting was monitored by strain gauges and the modal properties determined by experimental modal analysis. The results obtained were used to debug the numerical model of rifle barrel shooting. Modal analysis of hybrid barrel samples were made to assess the consistency of the modal properties of produced prototypes.

Introduction

Accuracy and precision of shooting is one of the requirements for the development of rifle. In the framework of research project is the means to achieve the goal of using a hybrid barrel with steel core and composite wrap. The actual behavior of a conventional barrel during firing was monitored by strain gauges and accelerometer. The obtained data helped us to verify boundary conditions of the numerical model of shot from the barrel.

Experimental Investigation

Strain gauges were used to assess the behavior of the gun barrel during firing. Dominant bending stress has been assumed in the preparation phase of the experiment, therefore, strain gauges were installed into half bridge wiring. A limited number of available channels with sufficient sampling frequency (96 kHz) was another reason for selecting half bridge wiring with the exclusion of the influence of temperature and purely tensile strain component. Bending strain were monitored in two sections. Four strain gauges were evenly installed in each section in the longitudinal direction.

Flexural properties of the test barrel were evident after the first series of experiments, the measured bending waveforms strain had a frequency corresponding to the first natural frequency of the barrel. The size of the bending deformation in the vertical direction was approximately three times bigger than the size of the bending strain in the horizontal direction.

Making of operational modal analysis was planning, but the accelerometer was damaged during the measurement, high jerk values were probably the reason. Experimental modal analysis was used for determination of dynamic properties of the barrel and the whole gun.

The question of the size of other strain components during shot was the reason another series of experiments [1]. Torsional component of strain being monitored by the shear strain gages, (V-shaped strain gauge with two grids and half bridge connection) installed between sections with longitudinal strain gauges.

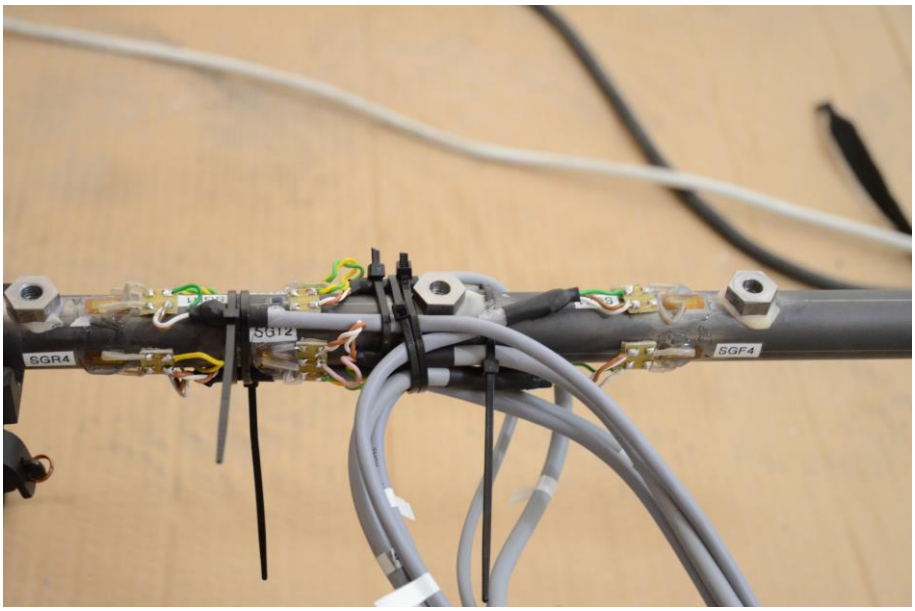

Fig. 1 Strain gauges installed on the rifle barrel

Whole set of strain gauges can be seen in Fig. 1. Gauges used in previous measurements for monitoring vertical bending, were connected via a three wire quarter bridge circuit. With regard to possible parasitic effect of temperature on the measured strain, a temperature of barrel surface was monitored by platinum resistance thermometer. Four channels were measured with high sampling frequency (96 kHz), the remaining channels were monitored with a lower frequency (19 kHz) by means other strain gauge units. Both units were synchronized by means fireware connection.

Muzzle velocity was measured by means photocell, when small scatter of velocities was recorded.

Purely tensile deformations were measured immediately after firing, these were quickly replaced by the bending deformations of a larger size. Shear strain measured during firing are much smaller than the bending deformation. The temperature of the barrel after the shot has risen by a few degrees of Celsius.

Numerical Analysis

Numerical model of same situation was made in Finite Element software, when elements with eight nodes and reduced integration and explicit solution were used [2]. The rifle barrel was modeled using planar symmetry and together with bolt assembly. The shot was modeled as a pressure impulse in the chamber of the barrel with propagation of pressure in barrel by means user subroutine. The simulation was computed until the bullet left the rifle barrel. The strains were recorded in places of strain gauges. Computed deformation of the rifle barrel during the shooting can be seen in Fig. 2.

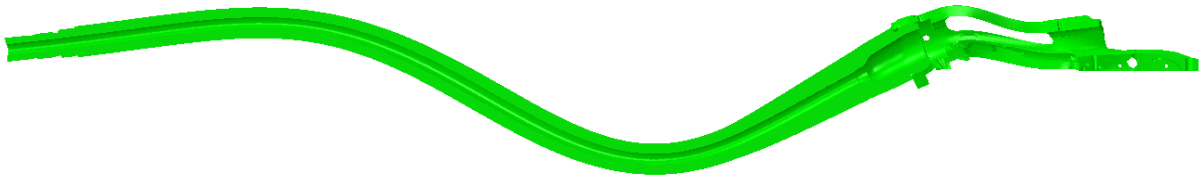

Fig. 2 Magnified deformation of the rifle barrel during the shooting computed by FEM.

Example of comparing measured and computed bending strain in one section can be seen in Fig. 3 Strain data were normalized to biggest value of measured strain.

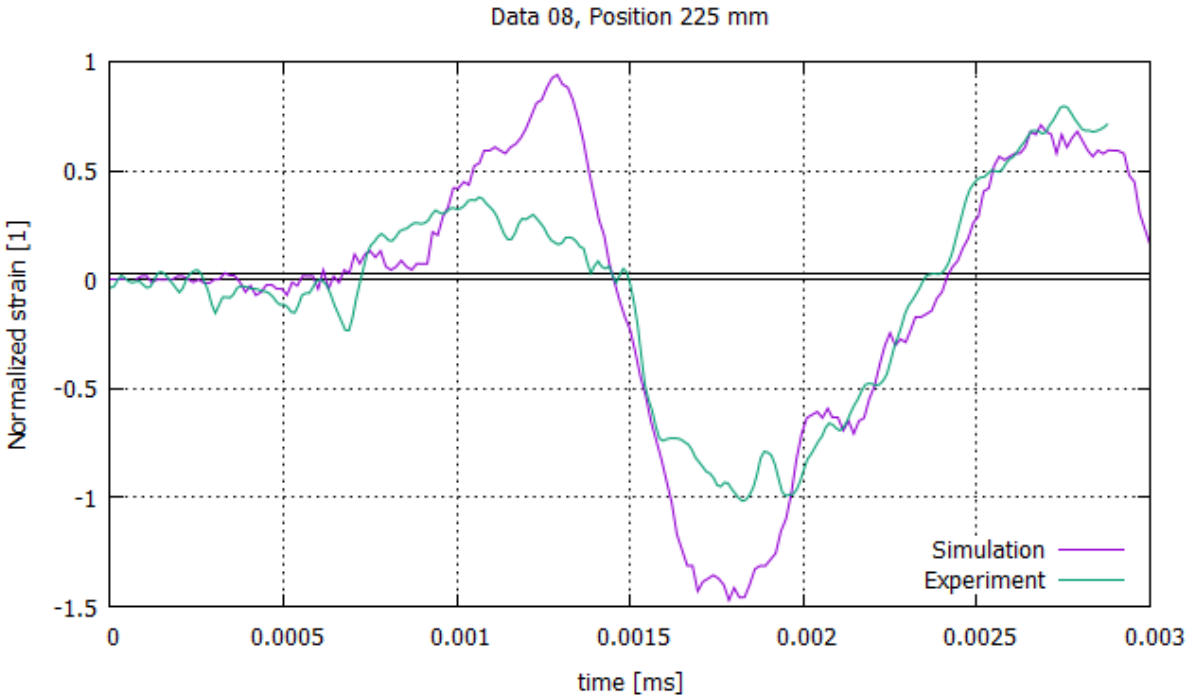

Fig. 3 Comparing of normalized measured and computed bending strain.

Based on the comparison of calculated and measured data, it is possible to state the suitability of the created numerical model for further research on hybrid composite barrel.

Modal Properties of Hybrid Barrel Samples

The question of the effect of the composition used for the manufacture of hybrids barrel was examined with regard to the modal properties of the final product.

Modal properties characterize the transverse stiffness of the barrel and its attenuation properties. Each measured sample was attached to rubber hinges with great compliance (see Fig. 4). For the excitation, the impact hammer was used to measure the excitation time in the plastic tip of the tool. The results of the measurements were processed in the ModalView software environment by the Polyfit algorithm to obtain their own frequencies, the respective modal damping and the oscillation shapes.

A total number of 20 different test specimens of composite prototypes of barrel were measured. The measurement showed good repeatability for the samples produced by the same technology and the same design. The results are suitable for verification of computational and optimization design tools.

Fig. 4 Barrel sample fixation during EMA measurement.

Conclusions

Characteristics of a conventional barrel were identified during shooting. A numerical model, with a good agreement with experiment, was created. Measurement of the modal properties of the prototypes specimens is used to identify the composition that was used to produce a functional porotype on the hybrid barrel. This barrel will be subjected to measurements to compare properties with the original conventional product.

Acknowledgement

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