

DESIGN, DEVELOPMENT AND TESTING OF SPLIT HOPKINSON TENSION AND COMPRESSION BAR SETUP FOR HIGH STRAIN RATE MATERIAL TESTING

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by

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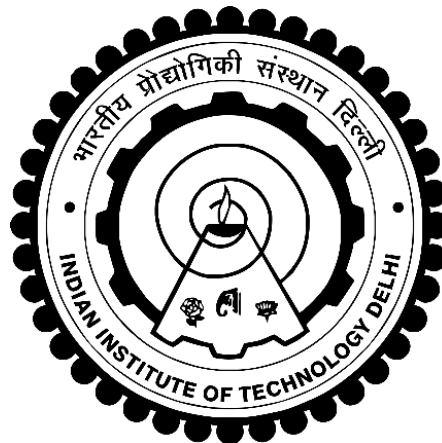
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This thesis work is dedicated to

My family

CERTIFICATE

I hereby certify that the dissertation entitled “Design, Development and Testing of Split Hopkinson Tension and Compression Bar Setup for High Strain Rate Material Testing” submitted by Mr. Makhan Singh in fulfillment of the award of Doctor of Philosophy in Mechanical Engineering Department of the Indian Institute of Technology Delhi is an authentic record of the investigations carried out by him under my guidance and supervision. The presented work has fulfilled the requirement for the submission of this thesis and has reached the required criterion to the best of my knowledge and belief.

The research work has not been submitted previously for the award of any degree of any other university.

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Signature

Abstract

The recent advancements in the potential development of composite materials have found numerous applications in the area of ballistic protection. The composite materials intended to be used for ballistic protection are strain rate dependent, i.e. they respond differently under quasi static and dynamic loading. During development stage, the performance of ballistic protection materials and their properties at high strain rate are of paramount importance in order to assess safety and structural integrity. Conformance to the specified standard levels of ballistic protection requires mechanical characterization of developed materials at high strain rates.

Over the years, Split Hopkinson Pressure Bar (SHPB) in various modes, i.e. tension, compression, torsion has been utilized for mechanical characterization of different materials at high strain rate. In this study, an innovative approach of SHPB for tensile and compressive high strain rate testing on a single setup is designed based on elasticity of materials and then developed and tested for variety of candidate materials. The dynamic effect of strain rate on stress strain curve is reported and analysed for different categories of materials. The mutual assessment of experimental observations and numerical predictions of SHPB setup along with their comparison is also presented. In addition to this, the numerous design modifications of SHPB are discussed in this study which primarily includes mechanisms for generation of stress waves, improvement in mounting of specimen, rationale for eliminating noise signals and adequate alignment of bars. In addition to this, the behavioural analysis of different metals, composites, ballistic protective materials when subjected to SHPB testing is discussed in detail.

Keywords: Split Hopkinson Pressure Bar, High Strain Rate Testing, High Strength Low Alloy Steels, Ballistic Protective Composite Materials

सार

मिश्रित सामग्रियों के संभावित विकास में हालिया प्रगति ने बैलिस्टिक सुरक्षा के क्षेत्र में कई अनुप्रयोग पाए हैं। बैलिस्टिक सुरक्षा के लिए उपयोग की जाने वाली मिश्रित सामग्री तनाव दर पर निर्भर होती है, यानी वे अर्ध स्थैतिक और गतिशील लोडिंग के तहत अलग-अलग प्रतिक्रिया करती हैं। विकास चरण के दौरान, सुरक्षा और संरचनात्मक अखंडता का आकलन करने के लिए उच्च तनाव दर पर बैलिस्टिक सुरक्षा सामग्रियों और उनके गुणों का प्रदर्शन अत्यंत महत्वपूर्ण है। बैलिस्टिक सुरक्षा के निर्दिष्ट मानक स्तरों के अनुरूप उच्च तनाव दर पर विकसित सामग्रियों के यांत्रिक लक्षण वर्णन की आवश्यकता होती है।

वर्षों से, स्प्लिट हॉपकिंसन प्रेशर बार (एसएचपीबी) का विभिन्न मोड में, यानी तनाव, संपीड़न, मरोड़ का उपयोग उच्च तनाव दर पर विभिन्न सामग्रियों के यांत्रिक लक्षण वर्णन के लिए किया गया है। इस अध्ययन में, एकल सेटअप पर तन्य और संपीड़ित उच्च तनाव दर परीक्षण के लिए एसएचपीबी का एक अभिनव दृष्टिकोण सामग्री की लोच के आधार पर डिजाइन किया गया है और फिर विभिन्न प्रकार की उम्मीदवार सामग्रियों के लिए विकसित और परीक्षण किया गया है। विभिन्न श्रेणियों की सामग्रियों के लिए तनाव तनाव वक्र पर तनाव दर के गतिशील प्रभाव की रिपोर्ट और विश्लेषण किया जाता है। एसएचपीबी सेटअप के प्रयोगात्मक अवलोकनों और संख्यात्मक भविष्यवाणियों का पारस्परिक मूल्यांकन और उनकी तुलना भी प्रस्तुत की गई है। इसके अलावा, इस अध्ययन में एसएचपीबी के कई डिजाइन संशोधनों पर चर्चा की गई है जिसमें मुख्य रूप से तनाव तरंगों की पीढ़ी के लिए तंत्र, नमूने के बढ़ते में सुधार, शोर संकेतों को खत्म करने के लिए तर्क और बार के पर्याप्त संरक्षण शामिल हैं। इसके अलावा, SHPB परीक्षण के अधीन होने पर विभिन्न धातुओं, कंपोजिट, बैलिस्टिक सुरक्षात्मक सामग्रियों के व्यावहारिक विश्लेषण पर विस्तार से चर्चा की गई है।

कीवर्ड: स्प्लिट हॉपकिंसन प्रेशर बार, उच्च तनाव दर परीक्षण, उच्च शक्ति कम मिश्र धातु इस्पात, बैलिस्टिक सुरक्षात्मक समग्र सामग्री

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