ISSUES IN DESIGN OF PROTECTIVE GEAR FOR BLAST APPLICATION

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by

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CERTIFICATE

This is to certify that the thesis entitled **Issues in design of protective gear for blast application** being submitted by Mr. Kanhaiya Lal Mishra to the Indian Institute of Technology, Delhi for the award of Doctor of Philosophy in Department of Mechanical Engineering is a record of bonafide research work carried out by him. He has worked under my guidance and has fulfilled the requirements for the submission of thesis, which, in my opinion, has reached the requisite standard.

The results contained in this thesis have not been submitted in part or full, to any University or Institute for the award of degree or diploma

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ABSTRACT

Anti-mine boots protect lower limbs of soldier, paramilitary and demining forces from accidental detonation of mine. These Anti-Mine Boots, which have blast reflecting and absorbing layers in the sole and minimize the physical damage to the lower limb. New design of Anti-Mine Boots involves new materials, in different layering pattern. These materials need testing in blast field environment as well as FEM simulation environment. FEM simulations reduced the mine field testing but for this validated material modal and material properties are required at high strain rate. Ceramic honeycomb structure has found importance, for its use in AMB for blast pressure attenuation. This thesis contributes to the development of methodology for finding the material modal and material properties of brittle ceramic honeycomb at high strain rate with validation check in mine blast experimental setup, for optimizing Anti-Mine boot design in thoroughly optimized FEM simulation environment.

Material properties of ceramic honeycomb is obtained through FEM inverse material mapping of SHPB experimental results. Material was modeled as linear brittle modal with failure stress and strain. Mine blast experiments were done to test the material alone and in sandwich structure form in blast environment and measured blast pressure was compared with FEM simulation result to draw the conclusion regarding ceramic honeycomb material use in design of AMB. All the parameters affecting output of FEM simulation were thoroughly investigated for valid simulation environment, with simulation of published mine blast experiments.

सारांश

माइन प्रतिरोधी जूते सैनिकों और अर्धसैनिकों के निचले अंग की माइन विस्फोट से रक्षा करतें हैं । माइन प्रतिरोधी जूते विस्फोट की उर्जा को अवशोनित करके निचले अंग की शारीरिक क्षति को कम करते हैं। नये माइन प्रतिरोधी जूते नये सामाग्री और नये विभिन्न लेयरिंग का उपयोग करते हैं । इन समाग्रियों को विस्फोट क्षेत्र के वातावरण क्षेत्र के साथ-साथ एफ ई एम सिमुलेशन वातावरण में परीक्षण की आवश्यकता है। एफ ई एम सिमुलेशन ने खान क्षेत्र परीक्षण को कम कर दिया है लेकिन इसके लिए उच्च तनाव पर मान्य सामाग्री माडल और भौतिक गुणों की अवश्यकता होती है सिरेमिक हनीकाम्ब संरचना को माइन विरोधी जूते में विस्फोट दवाव क्षीणन के लिए उपयोग में महत्व मिला है। यह क्षीतिस पूरी तरह से अनुकूलित एफ ई एम सिमुलेशन वातावरण में माइन प्रतिरोधी जूते के डिजाईन को अनुकूलित करने के लिए माइन विस्फोट प्रायोगिक सैटअप में सत्यापन जॉच के साथ उच्च तनाव पर भंगूर सिरेमिक हनिकाम्ब के सामाग्री मॉडल और भौतिक गुणों को खोजने के लिए कार्यप्रणाली के विकास में योगदान देता है।

सिरेमिक हनिकाम्ब के भौतिक गुण एस एच पी बी प्रयोगात्मक परिणामें के एफ ई एम प्रतिलोम सामाग्री मानचितरण के माध्यम से प्राप्त किये जाते हैं । सामाग्री को विफलता तनाव और तनाव के साथ रैखिक भंगुर मॉडल के रूप में तैयार किया गया था। माइन विस्फोट प्रयोग अकेले सामाग्री और सैंडविच सामाग्री संरचनास का परीक्षण करने के लिए किये गये थे । विस्फोट वातावरण में सैंडविच संरचना के रूप में माइन प्रतिरोधी जूते के डिजाइन उपयोग के बारे में नि-िकर्न निकालने के लिए एफ ई एम परिणाम के साथ प्रायोगिक माप विस्फोट दबाव की तुलना की गई थी। एफ ई एम सिमुलेशन के परिणाम को प्रभावित करने वाले सभी मापदण्डों की वैद्य सिमुलेशन वातावरण के लिए पूरी तरह से जॉच की गई थी। जिसमें प्रकाशित माईन विस्फोटों का अनुकरण किया गया था।

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NOMENCLATURE

SYBMOLS

P_{so}	Peak overpressure
t_A	Time of arrival
t_o^+	Positive phase duration
t_o^-	Negative phase duration
P_r	Reflected overpressure
P_0	Ambient pressure
ε_P	Effective plastic strain
$\dot{\varepsilon}_P$	Effective plastic strain rate

ABBREVIATIONS

PPE	Personal Protective Equipment
APM	Anti-Personal Mine
SSL	Simplified Lower Leg

CLL	Complex Lower Leg
FSL	Frangible Lower Leg
FE	Finite Element
FEM	Finite Element Method
DOB	Depth of Burial
TSS	Trauma Scoring System
AIS	Abbreviated Injury Scale
MTS	Mine Trauma Score
MES	Mangled Extremity Score