MECHANICAL BEHAVIOUR OF METALLIC MATERIALS UNDER DYNAMIC LOADS

by

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Dedicated to my
Parents and Teachers

CERTIFICATE

This is to certify that the thesis entitled **"Mechanical Behaviour of Metallic Materials under Dynamic Loads"** being submitted by **Mr. Nilamber Kumar Singh** to the Indian Institute of Technology Delhi, for the award of the degree of *Doctor of Philosophy* is a record of original bonafide research work carried out by him under our guidance and supervision.

Mr. Nilamber Kumar Singh has fulfilled all the prescribed requirements and the thesis is, in our opinion, worthy of consideration for the degree of *Doctor of Philosophy* in accordance with the regulations of the Institute.

The contents of this thesis have not been submitted to any other University or Institute for the award of any degree or diploma.

26.10.2012

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ABSTRACT

The deformation behaviour of structural components depends on the loading condition and the stress-strain relationship of the material. If the service load increases beyond elastic limit, material yields at the yield point, followed by large plastic deformation and eventual fracture / failure of the material and structures. Further, transportation and defence related structural components are sometimes exposed to extreme loading conditions, such as impact, shock, blast or collision and undergo severe plastic deformation and fracture. The stress-strain behaviour of materials under such high rates of loading is significantly different from those observed under quasi-static condition. Some materials are positive strain rate sensitive, some are negative strain rate sensitive, whereas, some other materials are insensitive to strain rate. Hence, the knowledge of the stress-strain behaviour of materials at different rates of loading is essential for the effective design of load bearing structural components.

Large scale experimental testing of structures under dynamic loading is costly and time consuming. Hence, designers prefer numerical simulation of actual structural components under extreme loading condition to understand the crashworthiness characteristics of structures. However, such numerical simulation requires an accurate mathematical model to represent the constitutive laws of materials during large plastic deformation under dynamic loads.

In the present work, an experimental investigation on the stress-strain behaviour of aluminium alloys, mild steels, other familiar grades of plain carbon steels and the new grades of advanced high strength steels (DP1200, DP1400, MP800HY and CP800) is carried out. The aluminium and plain carbon steels are widely used in the construction industry, whereas, these advanced high strength steels are prospective materials for

automobile industries. The stress-strain behaviour of specimens under quasi-static tension and compression are obtained from the *Universal Testing Machine.* At high loading rate, the stress wave propagation is more prominent and special experimental techniques are required to record the stress wave propagation in the materials. Medium and high strain rate experiments under dynamic tensile loads have been performed on the *Hydro-Pneumatic Machine* and *modified Hopkinson bar* respectively, whereas, specimens are tested on *split Hopkinson pressure bar* under dynamic compressive loads. The fracture surfaces of the broken tensile specimens are studied by scanning electron microscope at different strain rates. High speed camera has been used to monitor the large plastic deformation of mild steels. Thermal softening behaviour of advanced high strength steels is also studied at quasi-static condition. The material parameters of the existing Cowper-Symonds and Johnson-Cook material models are determined based on the experimental results by curve fitting method and the suitability of these models to represent the flow stress of each material is examined.

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