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Prediction of residual stresses due to laser shock peening using eigenstrain methods

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Laser Shock Peening (LSP) is a surface treatment used to enhance the fatigue life of components. To realise the full potential of LSP, a method for predicting residual stresses arising from this process is required. Eigenstrain methods can meet this requirement in a computationally effective way. At the same time they could allow one to use residual stress data measured in simple geometries to predict the residual stress fields in complex geometries.

Five eigenstrain methods were validated and compared in terms of their predictive power. A database of laser peened Aluminium Alloy 7075 flat plates was used to validate the methods. Three methods actually yielded results. Although none of these methods was categorically found to be the best, Coratella's method was rated as the best, based on its performance statistics. In addition, it is the simplest and quickest method from those tested. This method was used in the second part of the project.

The insensitivity of eigenstrains to geometry was also tested, using simple benchmark geometries, representative of features commonly encountered in engineering. These benchmark samples were previously generated in a research collaboration with the US Air Force Research Laboratory, University of Dayton Research Institute, and Wright-Patterson Air Force Base. Generally, the assumption was found to hold, except when the peened surface is a sharp edge.

The second part of the project aimed to study the effects of component geometry on LSP-induced residual stresses, in commonly encountered geometric features in engineering. The geometries selected were cuboid samples, spheres, cylinders, fillets, structural angles, and channels. A sample was chosen from the database of peened AA7075 samples to be the basis of this study. The eigenstrain distribution was extracted from this sample and imposed on various parameter combinations of the aforementioned geometries. The aim was to study the effects of specifically chosen geometric parameters on the residual stresses due to LSP.

A critical assumption made in the second part of the project was that LSP-induced eigenstrains are insensitive to geometric parameters. This assumption was based on the Principal of Transferability of Eigenstrain. Concern was raised regarding whether this principal holds for thin or small samples. It was hypothesised that for thin/small samples, the attenuation of the LSP-induced shock wave might be modified, leading to a different eigenstrain distribution. This concern is not universal, but limited to some specific parameters. Nevertheless, a study was conducted confirming the Principle of Transferability of Eigenstrain, showing that the assumption of insensitivity of eigenstrain to geometry holds, at least in some circumstances. Similar studies in literature affirm this.

The method has a weakness in predicting residual stresses through peened edges. This was attributed to the overlapping of different peened zones that occurs when peening over an edge, as well as the effect of the edge on the underlying eigenstrain distribution.

It was found that the residual stresses arising from LSP are insensitive to size in larger components. For smaller geometries, the residual stresses vary with changing size of the geometry but they tend to converge to specific values. It was also found that the maximum tensile stresses decrease with increasing size, and maximum compressive stresses tend to increase with increasing size, though this

is not always the case. These two facts seem to indicate that LSP has a more positive effect on larger components than smaller ones.

At the outset, it was envisaged that eigenstrain methods would be used to optimise the LSP process for actual components in industrial applications. While in principle, the method studied in this project may meet this need, there are some weaknesses that need to be overcome before it is fit for such a purpose. Recommendations are made on some steps that may overcome these weaknesses and on how this method could possibly be used in conjunction with other methods to achieve this purpose.