INVESTIGATION OF SHAPE MEMORY ALLOY BASED CLAMPING DEVICES FOR VIBRATION DAMPING AND HEAT DISSIPATION IN THE MACHINING OPERATIONS

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Abstract— With the industrial revolution and increasing demands for products, a good throughput along with high accuracy, quality and finish is required. For achieving this, proper machine and components are required. For firm gripping of work pieces during various machining operations like grinding, drilling etc. a proper clamping device is mandatory so that the machining could be carried out properly and accurately. In this work, Shape Memory Alloys (SMA) is used to enhance the gripping capabilities of a clamping device. SMA is a great smart material in today's world application. Here, we have presented a clamping device with a SMA cuboidal enclosure. The paper proposes the use of an SMA enclosure around the clamps which can be helpful for firm gripping of work pieces during high-speed operations. Along with damping out vibrations of the work piece, the enclosure will provide an aid in proper thermal distribution or heat dissipation of the heat produced in machining. We have presented vibrational and thermal analysis of the CAD model of our work. The results were remarkable as temperature reduced from 73^0c to 40^0c and vibrational frequencies came down from 20000Hz to 2100Hz.

Keywords— SMA (Shape Memory Alloy), Enclosure, Parallel Clamp.

I. INTRODUCTION

In order to meet the high demands and quality assurance a company needs to provide proper products on time keeping throughput in mind. For this, good machines and its equipment are required. One of the important component of machine is parallel clamps (fig.1) that hold the work piece for machining. If the clamp is not proper, then there would be vibrations in the work piece leading to undesirable effects. Therefore, in this paper we have shown the benefits of SMA when used in the clamping device of the machinery.

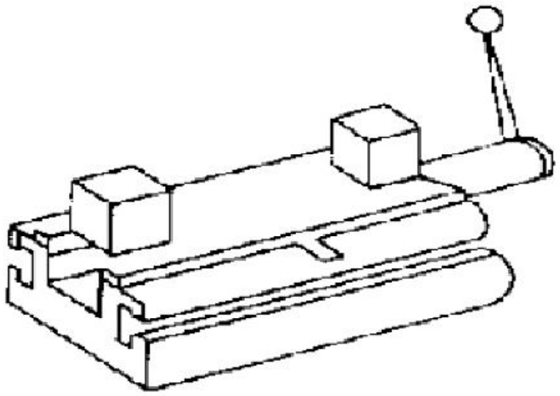


Fig.1 an illustration of parallel clamp from reference no. V

Shape memory alloy (Ni-Ti, Cu-Zn-Al, etc.) smart materials have their special feature of returning back to its original shape after deformation when heated within a temperature range of $60\text{-}130^0$. Shape memory alloys (SMAs) are featured by the competence to recover their original shape when a particular stimulus is applied. These materials have captivated considerable attention as potential actuators in the robotics, medical and automobile fields and also as seismic devices in machine tool operations.

With the use of SMA in the clamping device the work piece could be firmly held and high speed machining could be easily performed on work piece. Along with damping of vibrations this paper also showcases the use of SMA for increasing the heat dissipation rate of the heat produced during high speed operations. We have made a CAD model for our project and performed thermal and vibrational analysis on it to authenticate the increasing heat dissipation rate.

Looking at various previous works on use of SMA for damping vibrations of tools.*Sungcheul et al. [2015]* has done performance evaluation of a shape memory alloy tool holder for high-speed machining which includes the use of SMA rings around the tool holder to firmly grip the tool and dampen out the vibration at higher machining speeds. Also Guillem et al.*[2011]*,studied chatter in machining processeswhich describes the effect of machine tool chatter in surface finish, accuracy and productivity. There were various papers which focusses on the surface distortion or surface frictional distortion caused due to vibrations. Looking at all these problems we decided to come up with a remedyto damp the vibrations of work piece in order to produce products with high accuracy and proper finish. Therefore, we proposed an idea of making a SMA enclosure that can be fitted around the clamps which will help to firmly grip the work piece.

Another common problem with tools and workpiece is the heat dissipation and heat accumulation which results in poor surface finish due to presence of thermal patches and reduced tool life which can be solved in our paper with the help of same SMA enclosure.

II. THEORETICAL MODELLING

In certain machines the clamping of workpiece is done by parallel clamps which grips the workpiece for proper machining, but at times the clamps get loosen up due to which there are certain vibrations in the workpiece, now these vibrations cause two problems, oneimproper surface finish, inaccuracy and the other being surface frictional deformation due to friction between workpiece and the clamp due to continuous vibrations and rubbing.

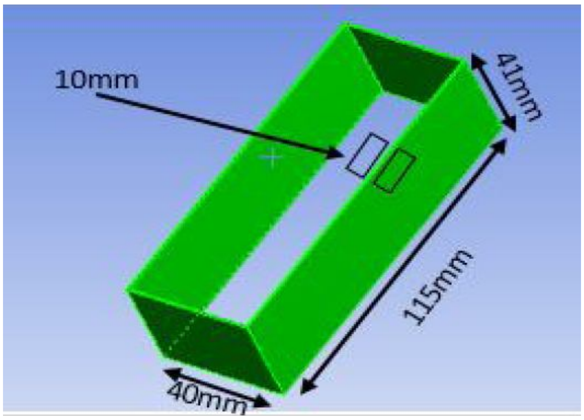


Fig.2 CAD model of SMA enclosure

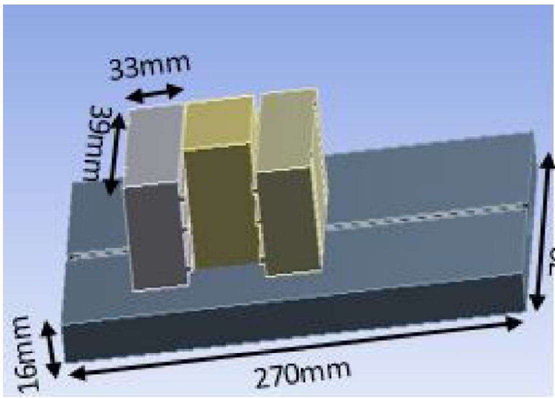


Fig.3 CAD model of parallel clamp

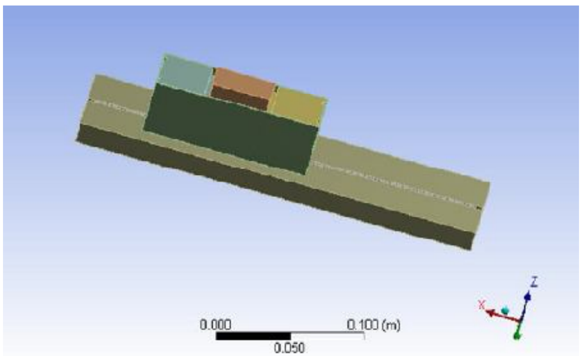


Fig.4 CAD model of clamp with SMA enclosure

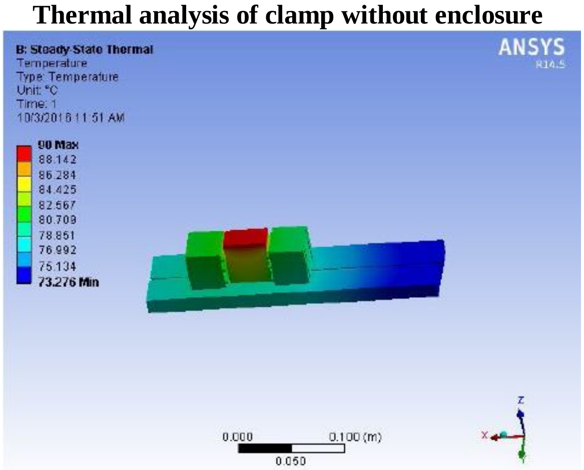
In order to prevent all this, wepropose a concept of SMA enclosure having cuboidal geometry(fig.3). The enclosure being cuboidal in shape will wrap around the clamp(fig.4) with an interference fit. The enclosure would be trained to actuate at 60^{o}c. it will be so trained that as soon as it actuates it will contract and firmly grip the clamps and restrict its motion. Now, since the enclosure contracts the clamps cannot have any outward movement and will firmly grip the workpiece due to which the workpiece could be machined at high speeds. if we make this enclosure with any other material and fix to the clamps with interference fit, then the problem would be that it won’t contract to fit tightly hold the clamps instead it will also start vibrating.

Second problem which arises is the reduction in tool life and thermal cracks due to large amount of heat generation. Since, the enclosure will stick around the clamps therefore conduction rate would be high and due to good thermal property of SMA, the heat dissipation rate would be high. We made a CAD model of our enclosure on creo 2.0 and performed thermal analysis of the same. The CAD model is displayed in the fig.2

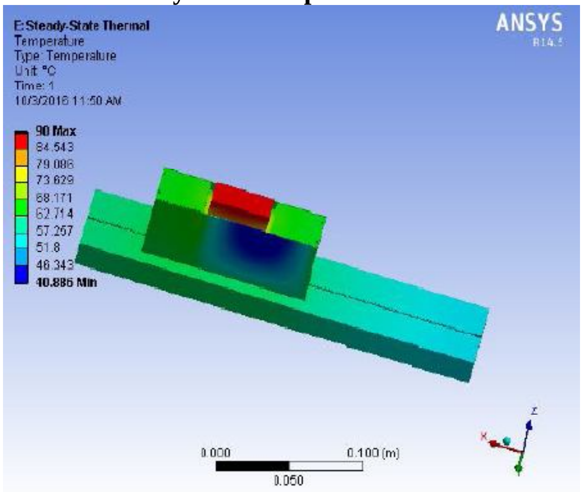
III. RESULTS AND DISCUSSIONS

Two analyses were performed on the CAD model with and without SMA enclosure and the results were recorded. First analysis was the thermal analysis in which the temperature on the surface of workpiece was kept 90^{0}c and the ambient temperature was kept 22^{0}cto ensure that SMA enclosure increases the heat dissipation rate. The analysis was done using ANSYS 14.5. The results were remarkable, since the temperature distribution in the model without SMA was 90^{0}c max and 73^{0}c min. which is high enough to distort surface finish and reduce tool life while the model in which the SMA was used the max. temperature was 90^{0}c but the min. temperature was 40^{0}c which is a drastic difference from the previous one. so from this it’s clearly visible that clamps with SMA enclosure proves to be better than without enclosure.

Thermal analysis of clamp without enclosure



Thermal analysis of clamp with SMA enclosure



The second analysis was vibrational analysis. Both the models were tested for vibrations and results were recorded. The results were in the form of deformation due to vibrations and vibrational frequency. When the model without SMA was analyzed, the vibrational frequencies were 20000Hz at the max level and 7402Hz at the min level and the deformation were also noticeable while when the SMA enclosure model was tested the vibrational frequencies dropped down to 2100Hz for the max and 475Hzfor the min. and the deformations were also considerably reduced. This shows that the enclosure structure can prove to be a good option for high speed operations.

CONCLUSION

By looking at the results of vibrational analysis that is drop of vibrational frequency from 20000Hz to 2100Hz and thermal analysis that is drop of temperature from 73^0c to 40^0c we can conclude that addition of an SMA enclosure will prove to be beneficial for machining with greater accuracy and high throughput can be achieved. The SMA enclosure not only damped vibrations but also helped in heat dissipation for better working of tool. Damping of vibrations will also reduce the frictional contact deformation. Henceforth looking at all results we can draw a conclusion that use of SMA enclosure will provide an aid in manufacturing.

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