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USE OF HOEKEN'S AND PANTOGRAPH MECHANISMS FOR CARPET SCRAPPING OPERATIONS

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ABSTRACT

For washing of carpets, scrapping is done using a wooden plank. The edge of the plank gives pressure on the carpet to remove dirt particles and water from the carpet surface. The plank follows a straight-line path on the carpet surface. In this paper Hoeken's and Pantograph mechanisms are used to obtain a straight-line path for carpet scrapping. Hoeken's four-bar mechanism can produce the same desired path, but the length is very small. The Pantograph mechanism is attached to magnify the length so that the scrapping length per stroke is same as that by the human operator. Combining these two mechanisms a carpet scrapping machine is developed for carpet cleaning purposes. The machine has been designed according to the force required to remove water and dirt particles from the carpet. It is driven by an electric motor and can move in any direction on the carpet.

INTRODUCTION

India is one of the biggest exporter of carpets in the world. Carpet processing involves several steps e.g., weaving (hand knotted), washing, drying, trimming, etc. Here the focus is carpet washing, which is done using a wooden scrapper (Fig. 1) by a human being. It is a laborious and hazardous step, as several chemicals like caustic soda, etc. are used. A carpet cleaning machine by the name "Carpet Scrapping Machine" that can perform the same job as the human washer is developed for carpet cleaning processes. For manual washing a wooden plank is used which has an extended wooden handle as shown in Fig. 1. Pressure is applied on the wet carpet through the edge of plank to remove excess wool and water from the carpet surface. The edge of plank follows a closed path containing a straight-line and a parabolic curve as shown in Fig. 2. In order to generate the path for manual scrapping, Hoeken's four-bar mechanism is suitable [1].

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However, the size of the curve is small, so to enlarge the curve size, the Pantograph mechanism [2] is introduced. Using these two mechanisms a carpet scrapping machine is realized which is driven by an electric motor. For easy movement of the machine, the wheels of the machine are also powered.

PREVIOUS WORK

The purpose of washing of carpet is to remove water, dust particles, excess piles and chemical from the carpet surface. It needs a massage to open the piles and to provide shininess of the carpet. For this purpose, the first machine was developed to copy the action of the human washer called washerman. The machine used slider crank mechanism where the slider was the scrapper pad. The machine hit the carpet and removed water from the carpet surface. However, the machine was drawing back some dirty water on the already cleaned surface during the return stroke. So a modification was desired to exactly copy the washerman's action i.e. move the scrapper straight in the forward stroke and in a parabolic curve in the return stroke, as shown in Fig. 2.

To copy the profile made by the edge of wooden plank the Hoeken's mechanism [2] is proposed. This type of profile allows to throw water and dust particles in one direction and returns without touching the carpet like the washerman's scrapper.

DESIGN METHODOLOGY

The aim here is to develop a compact, lightweight, easily operated, economic machine. The design involves kinematic synthesis of the mechanisms and mechanical design of the components. In this paper kinematic synthesis is presented.

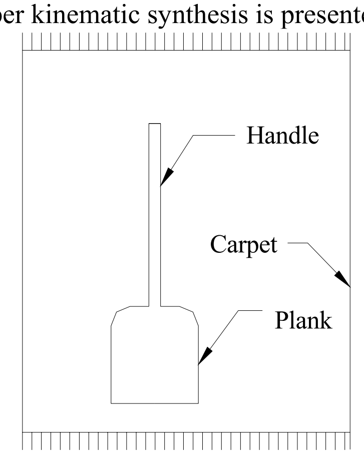

Fig. 1. Existing scrapper pad on carpet

The action of the washerman during the washing of the carpet was analysed. It was found that to remove water manually a straight-line motion is followed at the bottom edge of scrapper pad. After completing a desired area the pad is lifted up and stroked again on the carpet as indicated in Fig. 2. In the beginning the scrapper pad angle is about 50.5°, which gradually decreases along with forward motion. At the end the angle is approximately 29°.

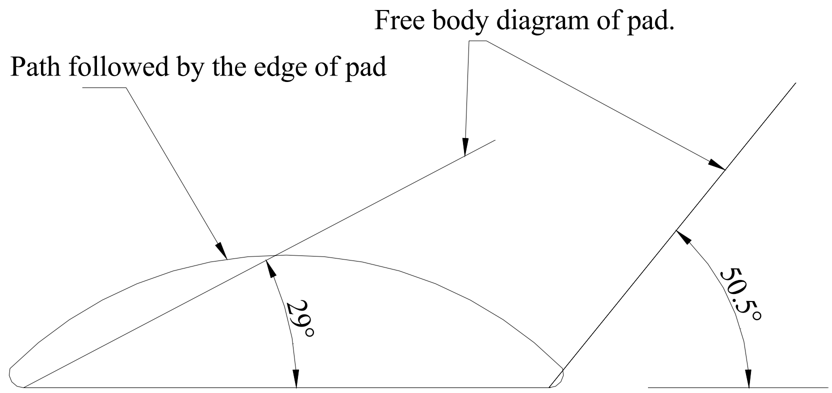

Fig. 2. Scrapper pad path

From the literature, [1] it is found that the Hoeken-type linkage offers the desired path. The mechanism has one crank that is suitable for driving using an electric motor. Its kinematic diagram is shown in Fig. 3, whose link length proportions are given below:

$OQ = L_1$, $OA = L_2$, $AC = AB + BC = L_3 + BC$, $BQ = L_4$ -----(1)

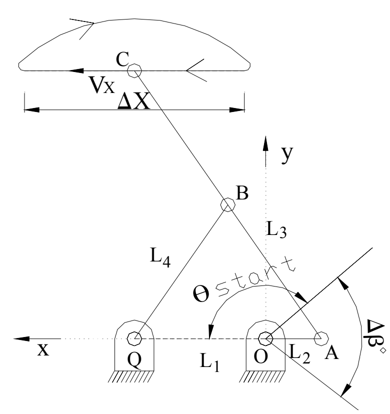

Fig. 3. Proportion of Hoeken's Mechanism

Hoeken-type linkage specified that

$$L_3 = L_4 = BC \qquad \text{------(2)}$$

Δx = Accurate portion of straight-line with near constant velocity.
V_x = Linear velocity along the straight-line portion of coupler.
$\Delta\beta$ = Crank angle corresponding to Δx.

In order to define the mechanism geometry, only two link ratios are needed e.g. L_1/L_2 and L_3/L_2. Hoeken's mechanism is a function of link ratio and it shows some errors in straightness and constant velocity. It is not possible to obtain an optimum straight-line with constant velocity. One can get optimum straight-line close to constant velocity or constant velocity with near about optimum straight-line motion. The errors in both straightness and velocity increase as $\Delta\beta$ increases. There are nine crank angles ranges from 20^o to 180^o along with link ratio [1]. For scrapping purpose optimum straight-line motion of coupler is the main requirement and constant velocity is not so important.

Author's first choice was to get minimum velocity error in 525 mm (stroke length used in manual scrapping) optimum straight-line path of scrapper pad. According to the Hoeken's mechanism, the corresponding link ratio's are as follows.

$$\Delta x/L_2 = 0.601;\ L_1/L_2 = 2.975;\ L_3/L_2 = 3.963 \qquad \text{-------(3)}$$

Here $\Delta x = 525$ mm.

Hence $L_1 = 2598.6$ mm; $L_2 = 873.5$ mm and $L_3 = 3461.6$ mm. -------(4)

The link lengths are too large to produce such a small length of straight path. By this mechanism it is difficult to introduce a small size portable lightweight machine. Thus the Pantograph mechanism [2] is introduced to magnify and copy the profile.

If $\Delta x = 150$ mm, and it can be magnified by 3.5 times a straightline of 525mm. is obtained. By using $\Delta x = 150$ mm, the obtained link lengths are as follows,

$$L_1 = 742.2 \text{ mm};\ L_2 = 249.5 \text{ mm and } L_3 = 989.0 \text{ mm}. \qquad \text{----(5)}$$

These values are found unsuitable for a lightweight and compact machine. To utilize the more portion of crank ratio angle $\Delta\beta$ is taken 160° or 180°, preferable angle is, $\Delta\beta = 180°$ and $\Delta x = 150$ mm. The corresponding link ratio's are

$$\Delta x/L_2 = 4.181;\ L_3/L_2 = 2.8 \text{ and } L_1/L_2 = 2.2, \qquad \text{-----(6)}$$

Hence, $L1 = 78.7$ mm, $L_2 = 35.8$ mm and $L_3 = 100.2$ mm -----(7)

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L_1 is the center distance between the crankshaft and rockershaft. Both will be bearing fitted. After designing it was found that the wall thickness between the bearings is very small and it caused problems during fabrication of the machine. This angle also causes the quick return motion of coupler motion, which gives vibration to the machine.

Now taking the crank ratio angle $\Delta\beta = 160°$ and $\Delta x = 150$ mm. The corresponding link ratio's are as follows

$\Delta x/L_2 = 3.933$; $L_3/L_2 = 3.025$ and $L1/L_2 = 2.35$, ---(8)

Hence, $L1 = 89.5$ mm, $L_2 = 38.1$ mm and $L_3 = 115.2$ mm -----(9)

These link lengths are suitable for the desired machine. Using these link lengths the same type of profile can be obtained as shown in Fig. 4.

The Pantograph is a four bar mechanism used to scale up or down an input motion. It consists of a jointed parallelogram EDFC, as shown in Fig. 4. It is made up of links coupled by revolute pairs. The links DE and DF are extended to G and T respectively such that

$GE/GD = EC/DT$. ----(10)

Thus, for all relative positions of the links, the triangles GEC and GDT are similar and the points G, C and T are in one straight-line. It may be proved that point T traces out the same path as described by point C [2]. The point G is fixed to the frame of the machine by means of a revolute pair, and C is attached to the coupler point, which has a specified motion relative to the frame. Then T copies the motion of C but magnified by 3.5 times due to the link proportions chosen for the Pantograph mechanism. The combined mechanisms with the paths are shown in Fig. 4.

Based on the practical considerations the dimensions of links of the Pantograph mechanism are:

GE = 95.6 mm, GD = 3.5 x 95.6= 334.6 mm, ED = 334.6 – 95.6 = 239 mm

CE = ED = DF = FC = 239 mm and DT = 3.5 x 239 = 836.5 mm

The AUTOCAD drawing of the "Carpet Scrapping Machine" based on the combination of Hoeken's and Pantograph mechanism is shown in Fig. 5. In short, the machine power comes from a motor to the crankshaft through reduction gearbox. Crankshaft consists of two cranks, on both sides of the machine. While the crank revolves at 45 rpm and rocker oscillates to the point Q. Two sets of Hoeken's and Pantograph mechanisms generate the washerman's scrapper movement. All the links are made of plain carbon steel, while the scrapper pad is made of polypropylene.

The main components of the carpet scrapping machine are:

Crank: 2; Rocker: 2; Coupler: 2; Crankshaft: 1; Rockershaft: 2; Bearing block: 6;
Scrapper pad: 1; Links: 8; Pin holder: 2; Motor: 1; Gear box: 1; Sprocket: 4; Wheel: 5

and few more parts which cannot be shown in the Fig. 6 due to the scale used for maximum page limit.

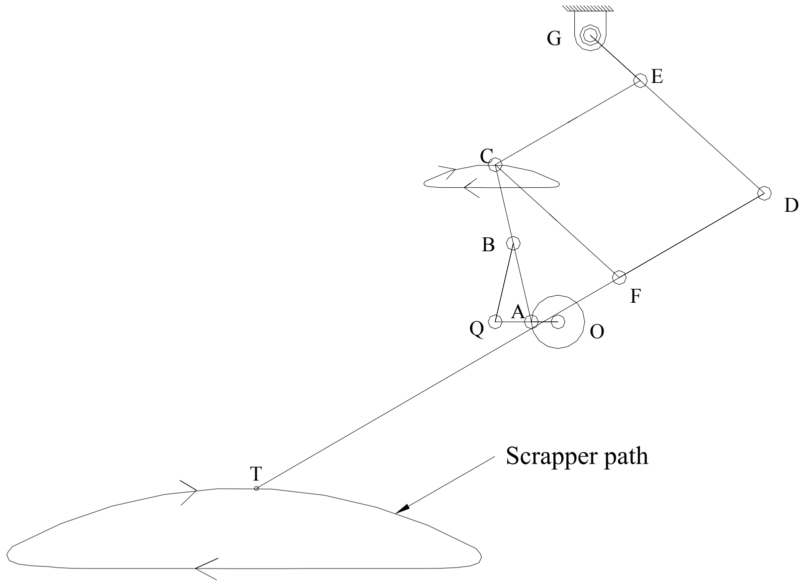

Fig. 4. Combination of Hoeken's and Pantograph mechanisms

TEST RESULTS

From A.C. supply power come to the 3 hp motor, running at 1440 rpm. Motor is connected with a reduction gearbox (ratio 1:30) through a belt drive. From the output shaft of gearbox power comes to the crankshaft through a chain drive. The speed of the crankshaft is fixed at 45 rpm. On both end of the crankshaft, two cranks are rotated which cause oscillation of the rockers. While crank rotates and rocker moves, coupler point makes the desired profile. Pantograph linkages magnify this profile and washes the carpet. The machine frame is constructed with angles, channels and square section. There are five wheels in the machine. Four of them are used for forward running. Two front wheels are power driven for easy movement. One small size caster wheel is provided at the back for tilting the machine and turning it. To guide the machine two set handles are included.

The machine has been sent to different carpet cleaning places in India, like Bhadohi, Mirzapur, Srinagar, Jaipur, Gwalior and Valsad for testing and to get feedback. Even though general functionality and performance are acceptable, the handling of the machine is difficult particularly during turning, as it has to be done manually. The steps will be taken in the next phase of this work.

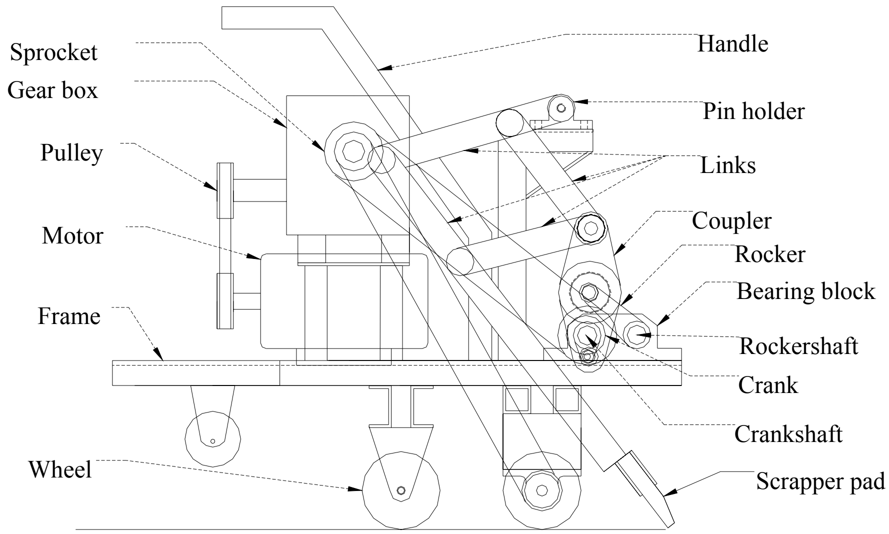

Fig. 5. AUTOCAD assembly drawing of the Carpet Scrapping Machine

Fig. 6. Scrapping Machine

CONCLUSIONS

A mechanized scrapping is introduced using two mechanism namely, Hoeken's and Pantograph mechanisms. The machine is expected to ease the manual scrapping process in less time, thus, removing the drudgery of the washerman. Alternatively washermen will be able to clean more carpets in a day using these machines, thus, improving their daily income.

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REFERENCES

[1] Norton, R. L., 1999, "Design of Machinery," Second Edition, McGraw-Hill, New Delhi.

[2] Bevan, Thomas, 1984, "The Theory of Machines," Third edition, CBS Publishers and Distributor, Delhi.